# DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-15

## HABITAT DEVELOPMENT FIELD INVESTIGATIONS
## BOLIVAR PENINSULA MARSH AND UPLAND
## HABITAT DEVELOPMENT SITE
## GALVESTON BAY, TEXAS

## APPENDIX B: BASELINE INVENTORY OF TERRESTRIAL FLORA, FAUNA, AND SEDIMENT CHEMISTRY

by

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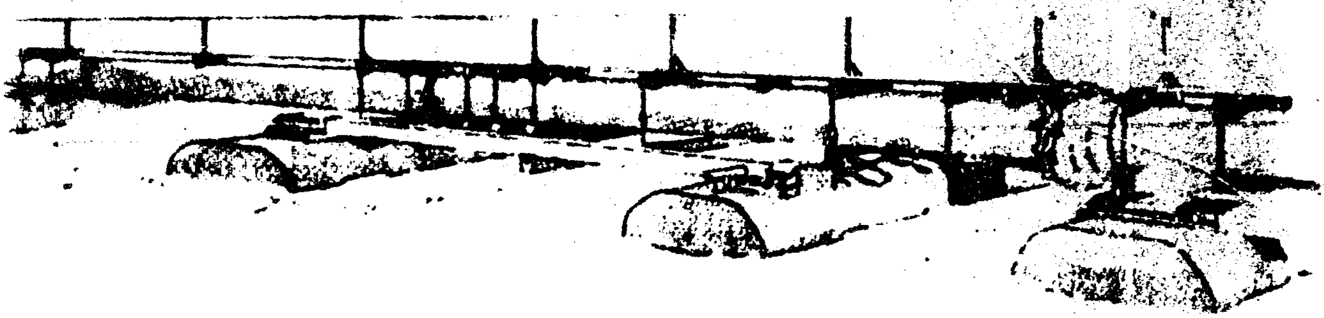

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

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| Birds | Habitats | Sediment sampling |
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| Field investigations | Plants (Botany) | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study involved collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

(Continued)

A total of 74 plant species representing 61 genera and 20 families were present at the study site. The dominant grasses were Spartina patens (marshay) and Andropogon spp. (bluestem). Forb density was over 435,000 plants/acre with Heterotheca subaxillaris (camphorweed) the most common. The Compositae contributed the greatest number of species. A woody plant density of over 3,250 plants/acre occurred. The dominant was Sesbania drummondii (drummond sesbania). The only other woody species that occurred was Croton punctatus (gulf croton). Standing crop biomass production on the study site exceeded 3,000 pounds/acre. The following six major plant communities were mapped, in order of area occupied: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, (e) Monarda citriodora, and (f) Spartina alterniflora.

A total of 98 bird species were identified, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded, 3 of them domestic. The most common were hispid cotton rat, raccoon, and domestic goat. A total of 31 individuals representing 11 species of reptiles and amphibians were observed. Eighteen orders of macroinvertebrates were collected and identified.

Soil and sediment samples were sandy in texture to a depth of 107 cm. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and extractable orthophosphate varied but were present in low quantities. Values of Eh varied from +500 mv for oxidized horizons to near -240 mv in the intertidal area. The pH values of the sediments ranged from 7.00 to 8.50. Interstitial water did not contain excessive concentrations of ammonium-, nitrite- or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ. Total phosphorus and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water were similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to those for the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

SUMMARY

This study involved the collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

Seventy-four plant species representing 61 genera and 20 families were collected and identified. Vegetation of the study area had a basal cover of 13.2 percent and a litter cover of 15.8 percent. The Gramineae and Cyperaceae families accounted for most of the basal cover. *Spartina patens* (marshay)* and *Andropogon* spp. (bluestem) were the dominant grasses. Forb density on the study area was 437,778 plants/acre. The Compositae contributed more plants to forb density than any other family. *Heterotheca subaxillaris* (camphorweed) had the highest relative density and frequency. Woody plant species had a density of 3,279 plants/acre. September biomass production was 3,071 pounds/acre for the study area; bluestem and marshay dominated with 30.8 percent and 28.7 percent of the total production, respectively.

Six plant communities were delineated on the basis of basal cover by dominants. These were: (a) *Andropogon perangustatus*, (b) *Spartina patens*, (c) *Sesbania*-mixed grass, (d) *Sporobolus virginicus-Distichlis spicata*, (e) *Monarda citriodora*, and (f) *Spartina alterniflora*. The *Andropogon perangustatus* and *Spartina patens* communities were the most extensive accounting for 37 percent and 25 percent of the study area, respectively. Each also produced over 4,100 pounds/acre biomass.

Forty-one bird species were recorded on the site during July, and the number increased to 50 in September. Overall the total was 58, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded on the site (three of them domestic), and the most common species were raccoon, hispid cotton rat, and domestic goat. There were

* This grass is also known as saltmeadow cordgrass in other regions of the nation.

11 species of reptiles and amphibians observed represented by a total of 31 individuals. Eighteen orders of macroinvertebrates were collected and identified. The most common forms were grasshopper, land snail, mud fiddler crab, and tiger beetle.

Soil and sediment samples were all sandy in texture to a depth of 107 cm. The least amount of sand reported at any depth was 88 percent. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and orthophosphate were variable but generally present in low quantities. Values of Eh varied from +500 mv for oxidized horizons located in the upland region to near -240 mv in the intertidal area. The Eh was closely related to moisture content. The pH values of the sediments ranged from 7.00 to 8.50.

Interstitial water samples did not contain excessive concentrations of ammonium-, nitrite-, or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ and was generally much lower. Total phosphorous and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ.

Chemical composition of the sediments generally corresponded to the sandy nature of the material. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water are similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

## PREFACE

This report presents the results of an investigation to describe quantitatively the flora, fauna, and sediment chemistry of a disposal site on Bolivar Peninsula, Galveston Bay, Texas. The investigation was conducted as a part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Contract No. DACW64-75-C-0101, entitled "Inventory and Assessment of Terrestrial Flora, Fauna, and Sediment Chemistry at Bolivar Peninsula Habitat Development Site, Galveston Bay, Texas, dated 12 June 1975, between the U. S. Army Engineer District, Galveston, and the College of Agriculture, Texas A&M University, College Station, Texas. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was monitored by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The Galveston District administered the contract for WES. Contracting Officer was COL D. S. McCoy, CE.

Parts I, II, III, IV, and VII were prepared by D. J. Herlocker and J. D. Dodd, Research Associate and Professor, respectively, in Range Science, Texas A&M University. B. W. Cain and B. J. Lee, Assistant Professor and Research Assistant, respectively, in Wildlife and Fisheries Sciences, Texas A&M University, prepared Part V. "Sediment Chemistry," Part VI, was prepared by L. R. Hossner and C. Lindau, Associate Professor and Research Assistant, respectively, in Soil and Crop Sciences, Texas A&M University.

The contract monitors at WES were J. S. Boyce and H. H. Allen, EL. Project manager was H. K. Smith, Manager, Habitat Development Project, EL. John Harrison was Chief, EL.

The authors express appreciation to personnal of WES and the Galveston District for their cooperation during this project. Special appreciation is extended to S. L. Hatch and F. Waller for their assistance in plant identification.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the conduct of the contract and the preparation of this report. Mr. F. R. Brown was Technical Director.

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## CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| inches | 2.54 | centimetres |
| feet | 0.3048 | metres |
| miles (U.S. statute) | 1.609344 | kilometres |
| square feet | 0.09290304 | square metres |
| square miles (U.S. statute) | 2.589988 | square kilometres |
| acres | 4046.856 | square metres |
| cubic yards | 0.7645549 | cubic metres |
| pounds (mass) | 0.4535924 | kilograms |
| miles (U.S. statute) per hour | 1.609344 | kilometres per hour |

BASELINE INVENTORY OF TERRESTRIAL
FLORA, FAUNA, AND SEDIMENT CHEMISTRY

## PART I: INTRODUCTION

1. Coastal marsh comprises 1,250 square miles* and is the most important land resource area on the Texas coast (Godfrey et al. 1973). Marsh is important in flood control and water quality, provides excellent wildlife habitat, and is a valuable source of nutrients for livestock and marine life (National Aeronautics and Space Administration (NASA) 1974). One-third of the population and nearly one-third of the industry of Texas is located on the Gulf coast (Fisher et al. 1972). This has had a serious impact on coastal marshes. Hundreds of acres are filled each year and the land use changed (NASA 1974). Thus, it is important to consider ways and means of maintaining and/or reestablishing marsh.

2. Approximately 2.3 percent of the coast marsh resource area has been set aside for dredged material sites (U.S. Army Corps of Engineers (USCE).1975a). These sites provide substrates for marsh development (especially open-water sites, which comprise about 48 percent of the total). In these areas, few other competitive land uses exist. Thus, an opportunity is provided to investigate the feasibility of marsh establishment on dredged material disposal sites.

3. This study involves the feasibility of using dredged material as a substrate for development of salt marshes along the upper Texas coast. Phase I involves collection of baseline data prior to development. Objectives include (a) survey and evaluation of historical data and literature pertinent to the study site, (b) inventory of avian, mammal, and macroinvertebrate populations inhabiting the study site, (c) inventory of vegetation including preparation of a vegetation map, and (d) determination of specific soil chemical properties of the study area prior to deposition of dredged material.

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*A table of factors for converting U.S. customary units of measurements to metric (SI) units is given on page 9.

## PART II: DESCRIPTION OF AREA

4. Bolivar Peninsula forms the eastern end of a chain of sand barriers that extend almost 600 miles along the Mexican and Texas coasts. The Bolivar Peninsula has developed as an offshore sand bar since the post-Pleistocene rise in sea level about 4000 years ago (Lankford and Rehkemper 1969). It is maintained by marine sedimentation processes, primarily on the Gulf shore. However, some sediment is also transported by sea water washing over the barrier to the bay (NASA 1974). River-transported sediments are negligible (USCE 1968). The peninsula is typically level with occasional elevations of 5 to 10 feet where old dunes occur (U.S. Geological Survey (USGS) 1954a, 1954b, 1954c, 1962a, 1962b).

5. The Galveston area annually receives about 40 inches precipitation, primarily between May and August. High humidities and moderate temperatures reflect proximity to the Gulf (National Oceanic and Atmospheric Administration (NOAA) 1974). Most of the year, prevailing winds are from the south and southeast (USCE 1968). Average velocity is about 11 mph (Lankford and Rehkemper 1969).

6. North of the Bolivar Peninsula, tides in Galveston Bay average about 6 feet and range about 1 foot in amplitude (0.79-1.81 feet above mean sea level) (USCE 1975b). Prevailing south and southeast winds may raise this level 2-3 feet while north winds may lower it as much as 4 feet (Lankford and Rehkemper 1969).

7. Hurricanes are an important factor in the local climate. Since 1871, five tropical storms and seven hurricanes have passed over or near Bolivar Peninsula. There is a 23-percent chance of hurricane occurrence in any one year (Henry et al. 1975). Storm surge associated with hurricanes strongly influences erosional and depositional processes and often results in barrier washover (Lay and O'Neil 1942, NASA 1974, Henry et al. 1975). Storm surges over 8 feet are common, and surges from 15-20 feet have occurred at Galveston. The Bolivar Peninsula, which lies entirely below 15-foot elevation, is thus a prime area for flooding (Henry et al. 1975).

8. Bolivar Peninsula occurs within a soil association comprising the Harris, Veston, and Galveston soil series (Godfrey et al. 1973). These are saline clayey and loamy soils of marshes and sandy soils of beaches. Heavy, saline clays generally overlain by peat occur under marsh vegetation (Lay and O'Neil 1942).

9. Composition of vegetation primarily reflects topography and ground water salinity. Barrier flat vegetation dominated by Spartina patens (marshay) and S. spartinae (gulf cordgrass) occupies the seeward half of the Peninsula. Two large salt marshes occur on the bay side (NASA 1974).

10. Lists of important plant species have been compiled for marsh vegetation along the Texas coast (Gould 1975) and for eastern Galveston County (Waller 1974). The principal coastal marsh communities of East Texas have been described by Lay and O'Neil (1942). These are: saline marshes, dominated by Spartina alterniflora Loisel. (smooth cordgrass), brackish marshes dominated by marshay and Distichlis spicata (L.) Green (seashore saltgrass), and fresh marshes dominated by Typha angustifolia L. (narrowleaf cattail), T. latifolia L. (common cattail), Scirpus californicus (California bulrush), and Eleocharis quadrangulata (Michx.) R.&S. (squarestem spikesedge).

11. Texas marshes overlie a heavy mineral soil (often saline) topped by a peaty layer. They are generally formed through subsidence (0.2 foot/century in the Galveston area) and lie behind beach ridges that prevent direct influx of seawater except during hurricanes (Lay and O'Neil 1942, Lankford and Rehkemper 1969).

12. Muskrat populations were exploited on Bolivar Peninsula until a few decades ago (Lay and O'Neil 1942). Present land use includes livestock ranching (Lay and O'Neil 1942, NASA 1974), exploitation of oil and natural gas fields (Holstrum and Williams 1971), and permanent and summer residences and commercial establishments (USCE 1968). Oyster beds lie immediately offshore on the bay side. This is also a nursery area for fishes of Galveston Bay. It is used extensively for recreational boating and fishing (USCE 1968, 1970, Holstrum and Williams 1971). In addition, commercial shipping uses the Gulf Intra-Coastal Waterway (GIWW), which runs along the entire bay side of the peninsula. Dredging associated with the GIWW has been almost continuous along this stretch since completion in 193? (Lay and O'Neil 1942, USCE 1975c). Selected areas are dredged about every 2 years. The average quantity of materials dredged per contract is 1.6 million cubic yards (USCE 1975c).

13. The study site is located on Galveston Bay between Marsh and Baffle Points near the west end of Bolivar Peninsula. It ranges in elevation from -0.2 feet to about +10.0 feet mean sea level (USCE 1975d).

The location is between the GIWW and the bay in dredged material disposal area No. 41. This area has no containing levee system, unlike some other disposal areas (USCE 1970). Dredged material deposition occurs about every 4 years on this site; the last disposal was in 1971.

## PART III: PLOT AND SAMPLING DESIGN

14. The study area is rectangular, 2,000 by 600 feet, 27.5 acres in area. Of this, 14 acres is intertidal and supports little vegetation. The study area has been extended back to the GIWW to include upland vegetation communities. This added 14 acres to the total area.

15. A surveyed baseline forms the south edge of the study area (Figure 1). Thirty-nine topographic transects have been established at 50-foot intervals along and at right angles to the baseline and were surveyed to the bay side of the study area. These have been extended nontopographically back to the GIWW. This system of transects was a reference for subsequent surveys of vegetation, soils, and wildlife.

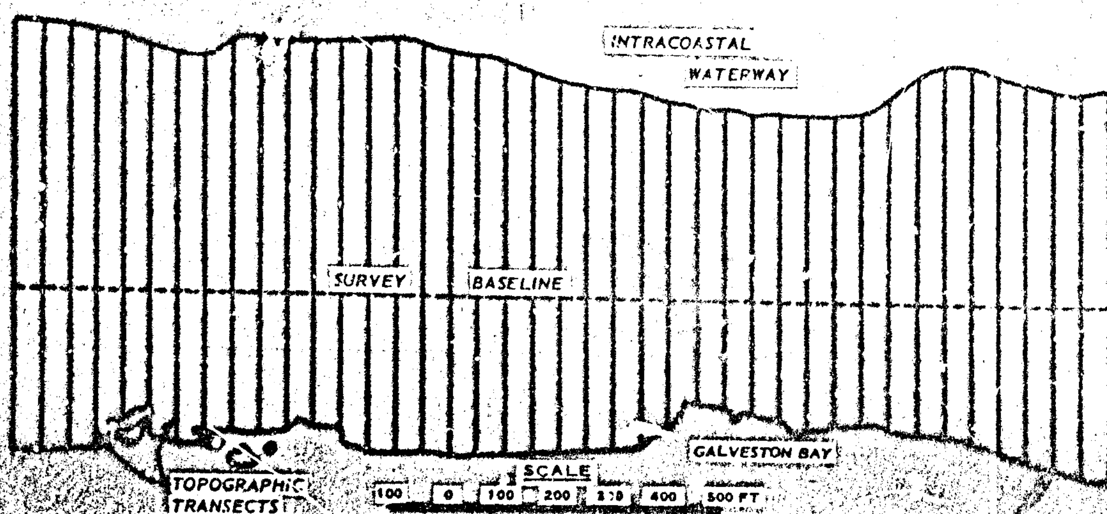


**Figure 1.** Study area at Bolivar Peninsula. The study area is located between the baseline and Galveston Bay

## PART IV: FLORA

16. The purpose of this research was to describe vegetation of the study area quantitatively. This included compiling a species list as well as defining the contribution of these species to the cover and production of the area. The major plant communities were identified and delineated.

### Methods

17. The study area was periodically and systematically searched for new plant species. All species encountered were pressed and later identified. All scientific and common names follow Gould (1975).

18. Vegetation sampling was conducted along three transects chosen at random in each of four 500-foot sections along the baseline. The surveyed baseline provided locations for the randomly located transects.

Phytosociological parameters

19. Basal cover and composition by species of grass and sedge, and the abundance of forb species were sampled with a 10-point frame (Levy and Madden 1933). Hits recorded included bare ground, litter, and plant species contacted at the soil surface (National Academy of Science-National Research Council (NAS-NRC) 1962). Density and frequency of forbs were determined with a square-foot quadrat (NAS-NRC 1962). Sample size and number were determined by the species-area curve (Oosting 1956). Density of woody plants was determined with an 11-square-foot quadrat. All of the above parameters were measured in August 1975. Sampling location was systematic along each transect. Thirty 10-point frame sets were utilized on each of the 12 transects (total sets = 360) to determine basal cover and plant composition. Twenty square-foot quadrats (total quadrats = 240), and five 11-square-foot (total quadrats = 60) quadrats were used per transect (from baseline to bay) to determine forb density and woody plant density, respectively.

Biomass

20. Biomass production was determined by techniques similar to Wiegert and Evans (1964). Plants were clipped at ground level on five 5.5-square-foot quadrats per transect (total quadrats = 60). Plant material was separated into important species. The remainder was placed

into miscellaneous categories of grass, sedge, and forb. Plant material on the soil surface was collected and placed in a litter category. All material was dried for 30 hours at 80° C, weighed, and reported as production in pounds per acre. Vegetation sampling and clipping for production were conducted at the close of vegetative growth periods in September and November 1975.

Communities

21. Boundaries between plant communities were visually noted along transects during vegetation sampling. These were used to stratify recorded data into plant communities for further analysis. In addition, a preliminary vegetation map was prepared for the study area. A final vegetation map was prepared by (a) establishing a 50-by-50-foot grid of stakes throughout the study area based on the 39 surveyed transect lines, and (b) using these to reference visually determined boundaries of plant communities. Procedures for mapping generally followed Brown (1954) and Kuchler (1967).

## Results

22. A total of 74 species representing 61 genera and 20 families have been collected and identified from the study site (Appendix A'). Over 62 percent of the flora occurred in three families, Gramineae, Cyperaceae, and Compositae (Table 1). This species list is incomplete since vegetation on the study site exhibits considerable seasonal variability. Thus, collection and identification must extend over a full year to ensure that all major species in the flora have been observed.

Basal cover

23. Overall, vegetative basal cover was 13.2 percent, litter was 15.8 percent, and bare soil surface 71 percent in August 1975. Dominance, in terms of high basal cover, was expressed primarily by species of the Gramineae and Cyperaceae (Table 2). Spartina patens (Marshay) and Andropogon perangustatus (bluestem) dominated the vegetation, contributing 20.1 percent and 13.6 percent of the basal cover, respectively. Five other species contributed 5 percent or more. One of these was from the Compositae, Heterotheca subaxillaris (camphorweed). Forb species contributed less to basal cover than did grass or sedge species.

Table 1

Vegetation Composition by Major Families

on the Bolivar Peninsula Study Site

(Sampled in August 1975)

| Family | No. Species | Total Flora (%) |
|---|---|---|
| Gramineae | 22 | 29.7 |
| Compositae | 15 | 20.3 |
| Cyperaceae | 9 | 12.2 |
| Leguminosae | 7 | 9.5 |
| Euphorbiaceae | 3 | 4.1 |
| Verbenaceae | 3 | 4.1 |
| Chenopodiaceae | 2 | 2.7 |
| Solanaceae | 2 | 2.7 |
| Total | 63 | 85.3 |

Table 2

Major Species Contributing to the Vegetation of the Bolivar Peninsula

Study Site Based on Basal Cover

| Species | Common Name | Species Composition (% Basal Cover) | Family |
|---|---|---|---|
| Spartina patens | Marshay | 20.1 | Gramineae |
| Andropogon perangustatus | Bluestem | 13.6 | Gramineae |
| Fimbristylis carolinianum | Fimbry | 8.6 | Cyperaceae |
| Sporobolus virginicus | Seashore dropseed | 6.5 | Gramineae |
| Scirpus americanus | American bulrush | 5.9 | Cyperaceae |
| Distichlis spicata | Seashore saltgrass | 5.4 | Gramineae |
| Heterotheca subaxillaris | Camphorweed | 5.0 | Compositae |
| Andropogon glomeratus | Bushy bluestem | 3.8 | Gramineae |
| Eragrostis oxylepis | Red lovegrass | 2.7 | Gramineae |
| Monarda citriodora | Lemon beebalm | 2.5 | Labiatae |
| Paspalum setaceum | Thin paspalum | 2.1 | Gramineae |

Note: Data collected with 10-point frame.

The most important forbs were camphorweed (5 percent), Monarda citriodora (lemon beebalm) (2.5 percent), and Chenopodium ambrosioides (wormseed goosefoot) (1 percent).

Frequency and density

24. Forb density was over 10 plants/square foot (437,738 plants/acre) in August 1975 (Table 3). The ratio of stems to plants was about 1.2 to 1. This indicated that single-stemmed plants were generally characteristic. Camphorweed contributed most to forb density (35.8 percent) and also was the most frequently occurring forb species in the study area (Table 3), indicating uniform distribution. The Compositae contributed more plants to forb density than any other family. The occurrence of colonies (aggregation of individuals of the same species) was not indicated since all important forb species had higher frequencies than relative densities. Wormseed goosefoot showed the greatest divergence between relative density and frequency, indicating uniform dispersal.

25. Only two species of woody plants were collected, Sesbania drummondii (drummond sesbania) and Croton punctatus (gulf croton). Density of woody plants over 2 feet tall was 3,279 plants/acre in August 1975. The most important species was drummond sesbania with 3,117 plants/acre, 95 percent of the total woody plant density. The stem-to-plant ratio of drummond sesbania was about 1.3:1, similar to that for most forb species. A stem-to-plant ratio of about 1.5 for all woody species reflected the numerous stems typical of gulf croton plants.

Biomass

26. Herbage biomass production for the study was area was over 3.070 pounds/acre in September 1975 (Table 4). Bluestem and marshay dominated in contribution to biomass production (30.8 and 28.7 percent of the total, respectively). The relative importance of both species in terms of production (Table 4) was greater than that expressed by basal cover (Table 2). The relative importance of most secondary species was similar for both basal cover and production; exceptions were that Fimbristylis carolinianum (fimbry) was less important for production and camphorweed was more important for production than indicated by basal cover. There

Table 3

Relative Density and Frequency of Occurrence of Important Forb Species on the Bolivar Peninsula Study Site

| Scientific Name | Common Name | Family | Absolute Density (No./acre) | Relative Density (%) | Frequency (%) |
|---|---|---|---|---|---|
| *Heterotheca subaxillaris* | Camphorweed | Compositae | 156,816 | 35.8 | 45.0 |
| *Aphanostephus skirrhobasis* | Coast dozedaisy | Compositae | 65,340 | 14.9 | 22.1 |
| *Monarda citriodora* | Lemon beebalm | Labitae | 60,984 | 13.9 | 20.4 |
| *Erigeron myrionactis* | Corpus Christi fleabane | Compositae | 56,628 | 12.9 | 33.7 |
| *Chenopodium ambrosioides* | Wormseed goosefoot | Chenopodiaceae | 21,780 | 5.0 | 29.6 |
| *Gaillardia pulchella* | Rosering gaillardia | Compositae | 17,424 | <5.0 | 8.7 |
| *Trifolium sp.* | | Leguminosae | 17,424 | <5.0 | 11.2 |
| *Ambrosia psilostachya* | Western ragweed | Compositae | 13,068 | <5.0 | 15.4 |

Table 4

Herbage Aerial Biomass Production by Species on the

Bolivar Peninsula Study Site

(Sampled in September 1975)

| Species | Common Name | Dry weight (pounds/acre) | Percent of Total |
|---|---|---|---|
| *Andropogon perangustatus* | Bluestem | 945.9 | 30.8 |
| *Spartina patens* | Marshay | 881.2 | 28.7 |
| *Sporobolus virginicus* | Seashore dropseed | 125.5 | 4.1 |
| *Scirpus americanus* | American bulrush | 103.9 | 3.4 |
| *Heterotheca subaxillaris* | Camphorweed | 101.2 | 3.3 |
| *Andropogon glomeratus* | Bushy bluestem | 85.0 | 2.8 |
| *Distichlis spicata* | Seashore saltgrass | 78.3 | 2.6 |
| *Monarda citriodora* | Lemon beebalm | 71.5 | 2.3 |
| *Fimbristylis carolinianum* | Fimbry | 64.8 | 2.1 |
| *Eustachys petraea* | No common name | 39.1 | 1.3 |
| *Spartina alterniflora* | Smooth cordgrass | 27.0 | 0.9 |
| *Paspalum setaceum* | Thin paspalum | 18.9 | 0.6 |
| Misc. grasses | | 334.6 | 10.9 |
| Misc. forbs | | 186.2 | 6.0 |
| Misc. sedges | | 8.1 | 0.2 |
| Total | | 3,071.2 | |
| Litter | | 887.9 | |

were no data available for comparing the September herbage biomass to other areas along Galveston Bay or the gulf coast.

27. The increase in relative importance of bluestem and marshay as expressed by biomass production over basal area was due to the relatively large clone size of some species. This was particularly evident in bluestem. In camphorweed the increase was due to the presence of multiple stems and large leaves.

Community delineation

28. Five major plant communities were delineated in the study area on the basis of species composition (Table 5 and Figure 2). These communities were named according to dominant species and were: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, and (e) Monarda citriodora. An additional community, dominated by Spartina alterniflora, also was apparent but covered only a small area that yielded only limited data.

29. In general, plant communities were clearly evident from both field surveys and vegetation data since each was dominated by species that were not abundant elsewhere (Table 6). Exceptions did occur in both the Andropogon perangustatus and Sesbania-mixed grass communities. Each contained a number of species important in both communities.

30. The Andropogon perangustatus and Spartina patens communities were the most extensive within the study area (baseline to bay), contributing 37 and 25 percent of the total study area, respectively (Table 5).

Cover, density, and frequency within communities

31. As shown in Table 6, vegetative basal cover within communities ranged from 7.8 percent (Sesbania-mixed grass) and 8 percent (Monarda citriodora) to 15.7 percent (Sporobolus-Distichlis and Spartina patens). Litter cover ranged from 1.9 percent (Sporobolus-Distichlis) to over 43 percent (Monarda citriodora) (Table 6).

32. The Sesbania-mixed grass community had the highest forb density (17.9 plants/square foot), while the Spartina patens community had the lowest (3.4 plants/square foot) (Table 7). Forb density of a community varied inversely with the grass basal cover. Low forb densities in the

Table 5

Major Plant Communities and Area Occupied on the Bolivar Peninsula Study Site (Baseline to Bay)

| Community | Common Name | Total Area (Acres) | Percent of Total |
|---|---|---|---|
| *Andropogon perangustatus* | Bluestem | 5.0 | 37 |
| *Spartina patens* | Marshhay | 3.4 | 25 |
| *Sesbania*-mixed grass | Sesbania | 2.3 | 17 |
| *Sporobolus virginicus* - *Distichlis spicata* | Seashore dropseed - Seashore saltgrass | 2.0 | 15 |
| *Monarda citriodora* | Lemon beebalm | 0.7 | 5 |
| *Spartina alterniflora* | Smooth cordgrass | 0.1 | 1 |
| Total | | 13.5 | |

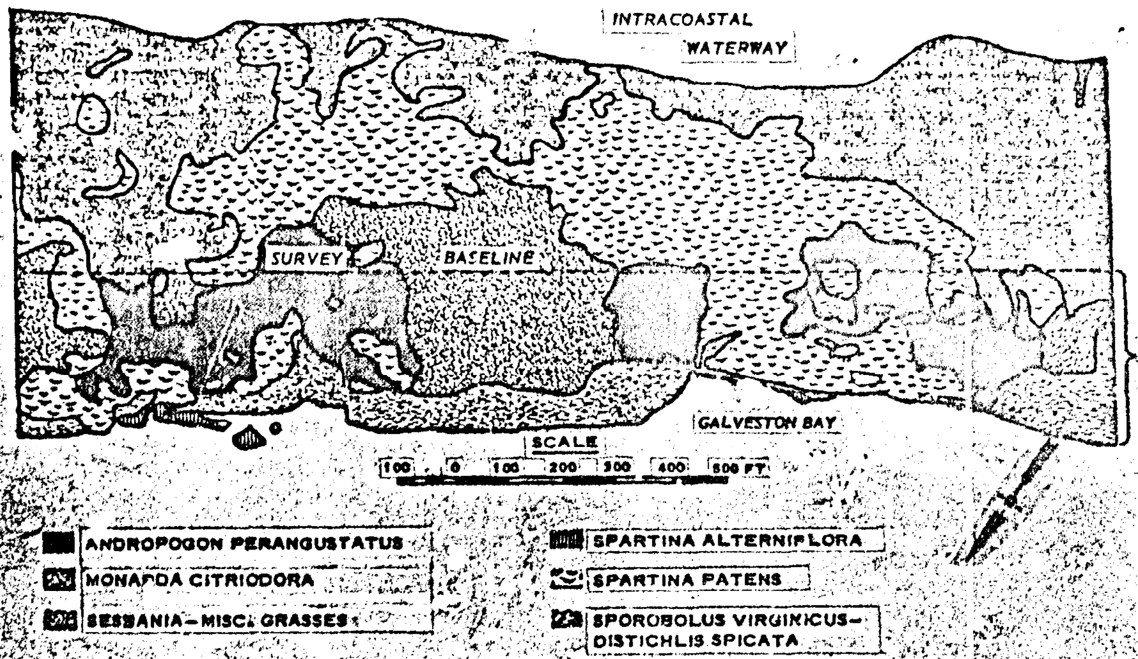


Figure 2. Map of Vegetation Communities on Study Site at Bolivar Habitat Development Site

Table 6

Percent Contribution of Major Species to Total Basal Cover Within Each Plant Community on the Bolivar Peninsula Study Site

| | Species | | | | | | | | | | | | Surface Ar Within Co (perce | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Community | Sesbania drummondii (Drummond sesbania) | Sporobolus virginicus (Seashore dropseed) | Distichlis spicata (Seashore saltgrass) | Spartina patens (Marshay) | Fimbristylis carolinianum (Fimbry) | Andropogon perangustatus (Bluestem) | Scirpus americanus (American bulrush) | Andropogon glomeratus (Bushy bluestem) | Eustachys petraea (No common nam | Heterotheca subaxillaris (Camphorweed) | Paspalum setaceum (Thin paspalum) | Monarda citriodora (Lemon beebalm) | Basal cover | Litter cover |
| Sporobolus-Distichlis | 36.0 | 39.7 | 33.3 | 6.4 | 6.4 | | | | | | | | 15.7 | 1.9 |
| Spartina patens | | | | 61.0 | 11.0 | | | | | | | | 15.7 | 20.0 |
| Andropogon | | | | 7.5 | 8.8 | 28.3 | 11.3 | 7.5 | 7.5 | 6.3 | | | 12.3 | 11.0 |
| Sesbania-mixed grass | | | | | 12.8 | 5.1 | 10.3 | 5.1 | | 17.9 | 12.8 | [illegible] | 7.8 | [illegible] |
| Monarda | | | | 8.3 | | | | | | | 16.7 | 37.5 | 8.0 | 43.6 |

Note: Only species with relative basal cover exceeding 5 percent are reported.

Percent Contribution to Total Density Within a Plant Community by Major Forb Species on the Bolivar Peninsula Study Site

| Community | Species: *Monarda citriodora* (Lemon beebalm) | *Heterotheca subaxillaris* (Camphorweed) | *Chenopodium ambrosioides* (Wormseed goosefoot) | *Erigeron myrionactis* (Corpus Christi fleabane) | Mean Forb Density: Plants/ sq. ft | Plants/ acre |
|---|---|---|---|---|---|---|
| Sesbania-mixed grass | | 58.2 | | | 17.9 | 779,724 |
| Andropogon | | 36.9 | | 24.9 | 11.4 | 496,584 |
| Monarda | 31.1 | | | | 10.8 | 470,448 |
| Sporobolus-Distichlis | | | 44.2 | | 4.7 | 204,732 |
| Spartina patens | | 35.9 | | | 3.4 | 148,104 |

**Note:** Only species with relative densities exceeding 20 percent are reported.

Spartina patens community resulted from the high basal and foliage covers of the dominant species that effectively reduced competition from forb species. The low forb densities in the Sporobolus-Distichlis community were likely related to an extreme environment including high soil salinity, exposure to wind and wave action, and the mat cover resulting from rhizomes of the dominant grasses. High forb densities in the Andropogon perangustatus and Sesbania-mixed grass communities were probably related to the stable mesic environment of the former and the relative lack of perennial grasses in the latter. The Sesbania-mixed grass community appeared to be undergoing rapid plant succession.

33. Differentiation between plant communities on the basis of forb species was more difficult than with grass species. Camphorweed was relatively dense in three communities, particularly the Sesbania-mixed grass community. The Andropogon perangustatus community was the only community with more than one forb species, camphorweed and Erigeron myrionactis (Corpus Christi fleabane), and both species had relative densities exceeding 20 percent.

34. Generally, forb species appeared to have a dispersed pattern. This was particularly true for Ambrosia psilostachya (western ragweed), which had less than 5 percent relative density on the study site (Table 3): in the Spartina patens community it had a 26.9-percent frequency and in the Sporobolus-Distichlis community it had a 24.4-percent frequency (Table 8). However, some colonies did occur. For example, camphorweed had a relative density of 35.9 percent (Table 7) and a frequency of 23.1 percent (Table 8) in the Spartina patens community; wormseed goosefoot had a 44.2-percent relative density (Table 7) and 17.1-percent frequency (Table 8) in the Sporobolus-Distichlis community.

35. The Andropogon perangustatus, Sesbania-mixed grass, and Monarda citriodora communities had high forb frequencies ranging from 51.6 percent in the Monarda community to 62.9 percent in the Andropogon community (Table 8). In addition, a large number of forbs occurred with frequencies exceeding 10 percent. These frequency data were consistent with forb densities in the three communities.

Table 8

Percent Frequency of Occurrence of Major Forb Plant Species

Within Each Plant Community on the

Bolivar Peninsula Study Site

| Community | Species: Monarda citriodora (Lemon beebalm) | Heterotheca subaxillaris (Camphorweed) | Chenopodium ambrosioides (Wormseed goosefoot) | Erigeron myrionactis (Corpus Christi fleabane) | Gaillardia pulchella (Rosering gaillardia) | Aphanostephus skirrhobasis (Coast dozedaisy) | Ambrosia psilostachya (Western ragweed) |
|---|---|---|---|---|---|---|---|
| Sporobolus-Distichlis | | | 17.1 | | | | 24.4 |
| Spartina patens | | 23.1 | | | | | 26.9 |
| Andropogon | | 55.1 | 33.7 | 62.9 | | | |
| Sesbania-mixed grass | 37.2 | 60.8 | 33.3 | 37.2 | | | |
| Monarda | 51.6 | 48.4 | 35.5 | 32.3 | 29.0 | 25.0 | |

Note: Only species with frequencies exceeding 20 percent are reported.

Biomass within communities

36. Data on biomass production in September 1975 emphasized the dominant species (based on species composition) in each community. However, based on biomass production, Spartina patens was the dominant in the Sporobolus-Distichlis community (Table 9), even though it occurred in only 2 of the 16 sampled quadrats. The contributions of camphorweed and miscellaneous forbs to biomass production in the Sesbania-mixed grass community suggested inclusion of these species as dominants. This was also true of Spartina patens in the Monarda community: based on total density (Table 7) and frequency of occurrence (Table 8) Spartina patens did not appear as a dominant in the Monarda community, but based on biomass (Table 9) it does. Thus, recognition of plant communities may differ slightly depending upon the criteria used.

37. The Spartina patens and Andropogon perangustatus communities had the greatest per-acre and total biomass production of all communities (Table 9). Although the Andropogon perangustatus community produced less biomass per acre than the Spartina patens community, it contributed the greatest total amount on the site because of the greater area occupied.

38. The Spartina alterniflora and Sesbania-mixed grass communities had the lowest biomass production per acre (Table 9). Thus, they contributed least to the total biomass production of the study area. The low biomass of the Spartina alterniflora community was a result of heavy grazing by goats and sheep. Under protection, biomass from this community would be much higher.

Change in biomass within communities

39. There was little change in the relative biomass production of the major plant communities between September and November (Table 10). Overall, total biomass in November was 9.7 percent less than in the study site in September. Four plant communities had lower standing biomass in November than in September, while two were higher. The increase in biomass from September to November of 625 pounds/acre in the Sesbania-mixed grass community was due to an increase in annual grass species. The two most prominent species were Aristida longespica

Table 9

Percent Contribution of Major Species to Herbage Biomass for Plant Communities on the Bolivar Peninsula Study Site

| Community | Species | | | | | | | | | Total Community Area (Acres) | Bio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spartina alterniflora (Smooth cordgrass) | Sporobolus virginicus (Seashore dropseed) | Distichlis spicata (Seashore saltgrass) | Spartina patens (Marshay) | Andropogon perangustatus (Bluestem) | Monarda citriodora (Lemon beebalm) | Heterotheca subaxillaris (Camphorweed) | Misc. grasses | Misc. forbs | | Pounds per Acre | Tota for Commun |
| **Spartina patens** | | | | 84.5 | | | | | | 3.4 | 4459.4 | 15,1 |
| **Andropogon** | | | | | 58.5 | | | 11.5 | | 5.0 | 4133.8 | 20,6 |
| **Sporobolus-Distichlis** | | 18.3 | 13.0 | 33.9 | | | | 12.1 | | 2.0 | 2252.8 | 4,5 |
| **Monarda** | | | | 14.6 | | 33.7 | | | 20.1 | 0.7 | 1874.4 | 1,3 |
| **Spartina alterniflora** | 92.8 | | | | | | | | | 0.1 | 1652.2 | 1 |
| **Sesbania-mixed grass** | | | | | 11.0 | | 22.4 | 28.9 | 16.8 | 2.3 | 1337.6 | 3,0 |

Note: Only species with relative biomass values exceeding 10 percent are reported. Data collected 1975.

Table 10

Difference between September and November Herbage Biomass

(pounds/acre) for each Community

| Community | Difference in Biomass (pounds/acre) between September and November 1975 | November Biomass Relative to September Biomass (%) |
|---|---|---|
| *Spartina patens* | -1040 | 76.7 |
| *Andropogon* | - 475 | 88.5 |
| *Sporobolus-Distichlis* | - 293 | 87.0 |
| *Monarda* | - 152 | 93.0 |
| *Spartina alterniflora* | +1136 | 168.8 |
| *Sesbania*-mixed grasses | + 625 | 146.8 |

(slimspike threeawn) and Eragrostis silveana (no common name). The increase measured in Spartina alterniflora community reflects reduced goat grazing in the fall. Decreases in biomass reflected slow growth and the onset of winter dormancy.

40. Litter weight in November was about 25% greater than in the study site in September (Table 11). Three communities, Andropogon, Sporobolus-Distichlis, and Spartina alterniflora increased in litter biomass. In contrast, litter biomass decreased in the Spartina patens, Sesbania-mixed grass, and Monarda communities. The high increase in the Spartina alterniflora community was due to sampling as only one plot occurred in this community and because goats stopped grazing from September until November.

41. The increase of litter biomass in the Andropogon and Sporobolus-Distichlis communities reflected the transfer of stand plant material to litter with the onset of winter dormancy. This correlates with the decrease in standing green biomass in both communities. The Spartina patens community decreased in both living biomass and litter from September to November. This implied a fast turnover (decomposition) of litter. Total litter increased in November from the level in September (Tables 12 and 4), although total production was down slightly. Andropogon perangustatus again contributed the most biomass.

42. A comparison of Tables 9 and 13 shows that in general, miscellaneous grasses increased in importance during the growth period September to November. The only exceptions were the Spartina alterniflora and Sporobolus-Distichlis communities. The increase in miscellaneous grasses in the Monarda community reflected the abrupt decrease in biomass production by Monarda citriodora, the community dominant in September. This decline was associated with establishment and growth of miscellaneous annual grass species. Annual grass species also were established during this period on bare soil in the Sesbania-mixed grasses community.

43. Considerable shift in percent contribution of the major species to community biomass was evident from September to November (Tables 9, 13). Increased biomass measured for Sporobolus virginicus as well as

Table 11

November Litter Biomass as a Percentage of that in September for each Community

| Community | Percent of September Litter Biomass |
|---|---|
| *Spartina patens* | 69.7 |
| *Sesbania*-mixed grass | 77.7 |
| *Monarda* | 96.9 |
| *Andropogon* | 154.0 |
| *Sporobolus-Distichlis* | 256.0 |
| *Spartina alterniflora* | 349.0 |
| Overall for site | 125.0 |

Table 12

Herbage Aerial Biomass Production by Species on the

Bolivar Peninsula Study Site

(Sampled in November 1975)

| Species | Common Name | Dry weight (pounds/acre) | Percent of Total |
|---|---|---|---|
| *Andropogon perangustatus* | Bluestem | 613.3 | 22.2 |
| *Spartina patens* | Marshay | 584.8 | 21.2 |
| *Sporobolus virginicus* | Seashore dropseed | 288.7 | 10.4 |
| *Scirpus americanus* | American bulrush | 141.6 | 5.1 |
| *Andropogon glomeratus* | Bushy bluestem | 124.1 | 4.4 |
| *Fimbristylis carolinianum* | Fimbry | 82.3 | 3.0 |
| *Heterotheca subaxillaris* | Camphorweed | 68.8 | 2.5 |
| *Eustachys petraea* | No common name | 44.5 | 1.6 |
| *Spartina alterniflora* | Smooth cordgrass | 31.0 | 1.1 |
| *Monarda citriodora* | Lemon beebalm | 17.5 | 0.6 |
| *Paspalum setaceum* | Thin paspalum | 6.7 | 0.2 |
| Misc. grass | | 615.3 | 22.2 |
| Misc. forbs | | 148.4 | 5.3 |
| Misc. sedges | | 6.7 | 0.2 |
| Total | | 2773.7 | |
| Litter | | 1108.9 | |

Percent Contribution of Major Species to Herbage Biomass for Plant Communities on the Bolivar Peninsula Study Site

| Community | *Spartina alterniflora* (Smooth cordgrass) | *Sporobolus virginicus* (Seashore dropseed) | *Spartina patens* (Marshay) | *Andropogon perangustatus* (Bluestem) | Misc. grass | Misc. forb | Total Community Area (Acres) | Biomass: Pounds per Acre | Biomass: Total for Community | Biomass: Per[illegible] To[illegible] Si[illegible] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Andropogon** | | | | 41.9 | 25.9 | | 5.0 | 3659 | 18295 | 45 |
| **Spartina patens** | | | 65.2 | | 12.3 | | 3.4 | 3419 | 11625 | 2[illegible] |
| **Spartina alterniflora** | 67.7 | 32.3 | | | | | 0.1 | 2788 | 279 | [illegible] |
| **Sesbania-mixed grasses** | | | 22.2 | | 37.6 | 12.8 | 2.3 | 1963 | 4515 | 1[illegible] |
| **Sporobolus-Distichlis** | | 49.9 | 17.0 | | 12.1 | | 2.0 | 1960 | 3920 | [illegible] |
| **Monarda** | | | 28.9 | | 30.9 | 17.5 | 0.7 | 1742 | 1219 | [illegible] |

**Note:** Only species with relative biomass values exceeding 10 percent are reported. Data collec[illegible] November 1975.

the decrease measured for *Spartina patens* and *Distichlis spicata* could reflect placement of samples.

44. The map (Figure 2) indicated that vegetation of the study area (baseline to bay) was more heterogeneous than indicated by casual observation. However, the initial plant community boundaries identified by reconnaissance and vegetation sampling were correct. The map indicated more clearly local dominance exhibited by species in areas too small to permit classification as a major community. Differences in vegetative composition reflected a number of environmental factors that influence the occurrence of plant communities: (a) distance from the bay (saline soils and wave and wind action), (b) rooting depth, and (c) age of dredged material deposits. The exact ways these factors influence vegetative composition will have to be determined by specific studies.

## PART V: FAUNA

45. In order to determine the response of wildlife populations to habitats created by dredged material disposal a baseline survey of the affected area must be accomplished prior to habitat alterations. This survey should give data concerning the diversity of animals present and an index to the degree of use of the area before the habitat alterations. Few reports are available on animal colonization of salt marshes established on dredged material (Cammer et al. 1974) or other manmade marshes (Herke 1971). Larimer (1968) discussed the possibilities for creating salt marshes in estuaries along the Atlantic and Gulf coasts.

46. Terrestrial vertebrates in Texas marshes have not been researched unless they were of game or other economic value (Lynch 1967, Chabreck 1972). The avian fauna is censused annually along the Texas coast (Cruickshank 1965-1974), but only recently has analysis of these data been attempted (Lee and Cain in preparation).

### Methods

47. Birds. The avifauna were censused by walking five transect lines that divided the study site into four equal areas. These transect lines were about 150 feet apart, running east and west for 2000 feet. Birds were recorded as seen or heard. Birds were surveyed for two hours from half an hour after sunrise on two consecutive mornings twice a month. A literature survey using annual bird counts (Cruickshank 1965-1974) was used to determine residency status.

48. Mammals. Small mammals were trapped on four consecutive nights monthly from October through December 1975. Sherman live traps baited with hen scratch, a nonodiferous prepared feed of primarily milo and corn, were placed in a 7.8-acre grid on the east side of the study site. The grid lines covered all vegetation types and were 50 feet apart, running from bay to waterway. Traps were spaced at 50 feet.

49. Captured small mammals were identified, toe-clipped, aged, sexed, and released at the collection point. Population estimates were made using a modified Schnabel (1938) estimator in the form

$$N = \frac{Mn}{1 + m} \quad \text{where } N = \text{total population}$$
$$M = \text{total marked animals}$$
$$n = \text{total catch}$$
$$m = \text{recaptures.}$$

This was used so that the time interval between trapping periods was not a factor in population trends.

50. Tomahawk live traps baited with small fish were set for larger mammals. They were also observed indirectly by looking for evidence of their presence (i.e. pellets, tracks, burrows). Goats (Capra hircus) were counted as they visited the study site.

51. Herptiles. Amphibians and reptiles were collected in conjunction with the bird and mammal surveys and with the use of a four-pronged rake to turn over debris. They were identified and released. Population estimates were not made.

52. Invertebrates. Macroinvertebrates, described herein as those invertebrates not passing through a 5-mm mesh screen, were sampled using sweep nets, sieves, a 1-$m^2$ frame, and a 0.3-$m^2$ frame. Collections were made on each site visit during July, August, and September 1975, and covered the entire site in a qualitative fashion.

53. Insects were collected by taking 20 sweeps with the net while walking through the herbaceous vegetation. Each sweep conincided with a step, and the area sampled was estimated at 20 m by 1 m for each sample. Five such samples were taken on each site visit. All terrestrial invertebrates were censused by placing a 1-$m^2$ frame over the vegetation and spraying the enclosed area with a pesticide (Raid for Garden Insects and Pests). The invertebrates were collected from the vegetation as it was clipped and spread out over a paper sack. Crustaceans were censused by placing a 1-$m^2$ frame on the ground and counting the burrows within the frame. Soil invertebrates were collected and counted by sifting 15 cm of soil from a 0.3-$m^2$ area through a sieve. Sampling for crustaceans and soil invertebrates was limited to the intertidal zone.

## Results

54. Birds. Ninety-eight species were observed. The avian fauna on the site consisted of 41 species during July and increased to

50 species in September (Table 14). The increase in September was due to fall migration. The avifauna decreased in October as some of the summer nesting birds moved south. The increase in November and December is due to the influx of winter residents, especially sparrow species (Table 14).

55. Thirty-four of the bird species sighted are considered permanent residents along the coast of Texas. There were 35 winter residents, 9 summer residents, and 20 migrants. Many of the resident species (19) feed on organisms that are found in Galveston Bay or on its intertidal shores, 12 feed on insects or seeds, and 3 others feed on carrion as well as insects and seeds.

56. Twelve of the species recorded on the site nest in the habitats available on Bolivar Peninsula. The killdeer, willet, and common nighthawks nest on bare areas, the eastern meadowlark uses grass, and the other species (Table 14) nest in the Sesbania or tall herbaceous plants.

57. A qualitative comparison of the beach and upland habitats showed that the upland had fewer species and lower diversity than the beach area. This is at least partly due to the importance of shore and marsh areas in the winter months, the only time this survey was done.

58. Mammals. Mammal diversity on the study site was not high, with only 13 species observed (Table 15), 3 of them domestic. The most common mammals were raccoon, hispid cotton rat, armadillo, and domestic goat. The goats, which wandered across the study site as they grazed on the peninsula, were estimated at 150 in number.

59. The small mammal survey collected 136 hispid cotton rats and 45 house mice. Table 16 gives population estimates.

60. Females composed 33.9% of the cotton rats trapped and males 66.1%, overall. The difference in ratios among months was not significant, but proportionally more males were caught in October than in November and November than in December.

61. Adult cotton rats were more often caught, composing 80% (average) of those captured. The low percentages of juveniles is probably related to the fact that socially subdominant cotton rats

Table 14

Monthly Bird Fauna of the Bolivar Peninsula Study Site

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Horned grebe (*Podiceps auritus*) | ( W) | - | - | - | - | + | - |
| Eared grebe (*Podiceps caspicus*) | ( W) | - | - | - | - | + | + |
| White pelican (*Pelecanus erythrorhynchos*) | (F,W) | - | - | - | + | + | + |
| Double-crested cormorant (*Phalacrocorax auritus*) | (F,W) | - | - | - | - | + | + |
| Anhinga (*Anhinga anhinga*) | (F,W) | - | - | - | + | - | - |
| Canada goose (*Branta canadensis*) | (F,W) | - | - | - | - | + | + |
| White-fronted goose (*Anser albifrons*) | (F,W) | - | - | - | - | - | + |
| Snow goose (*Chen hyperborea*) | (F,W) | - | - | - | + | + | + |
| Lesser scaup (*Aythya affinis*) | (F,W) | - | - | - | + | - | - |
| Marsh hawk (*Circus cyaneus*) | (F,M) | - | - | + | + | + | + |
| Harris hawk (*Parabuteo unicinctus*) | (F,M) | - | - | - | + | - | - |

Notes: B = sitting on bay shore or intertidal waters; F = flying over the site; P = perching on the ground or vegetation; R = permanent resident; M = winter or summer migrant; W = winter resident
+ = an identification made on the study site or flying over the site
- = not seen during this month
* = nested on the study site.

Table 14 (CONTINUED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Osprey (Pandion haliaetus) | (F,M) | - | - | - | - | + | - |
| Common egret (Casmerodius albus) | (F,W) | + | + | - | - | + | + |
| Cattle egret (Bubulcus ibis) | (P,R) | + | + | - | - | - | - |
| Snowy egret (Egretta thula) | (B,R) | + | - | + | - | + | - |
| Great blue heron (Ardea herodias) | (B,R) | + | + | + | + | + | + |
| Louisiana heron (Hydranassa tricolor) | (B,R) | + | + | + | - | + | - |
| Little blue heron (Florida caerulea) | (B,R) | + | - | - | - | - | - |
| Black-crowned night heron (Nycticorax nycticorax) | (F,R) | + | - | - | - | - | - |
| Yellow-crowned night heron (Nyctanassa violacea) | (F,R) | - | - | + | - | - | - |
| White-faced ibis (Plegadis chihi) | (F,M) | + | + | + | - | - | - |
| White ibis (Eudocimus albus) | (F,R) | - | - | + | - | - | - |
| Roseate spoonbill (Ajaia ajaja) | (F,M) | + | + | - | - | - | - |
| Virginia rail (Rallus limicola) | (P,W) | + | + | - | + | - | - |
| American avocet (Recurvirostra americana) | (B,M) | + | - | - | - | + | - |
| Black-necked stilt (Himantopus mexicanus) | (B,M) | + | - | - | - | - | - |

Table 14 (CONTINUED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Black-bellied plover (*Squatarola squatarola*) | (B,W) | + | + | + | + | + | + |
| Piping plover (*Charadrius melodus*) | (B,W) | - | + | + | - | + | - |
| Snowy plover (*Charadrius alexandrinus*) | (B,W) | - | - | + | + | + | + |
| Semipalmated plover (*Charadrius semipalmatus*) | (B,M) | - | + | - | - | - | - |
| Wilson's plover (*Charadrius wilsonia*) | (B,M) | + | + | + | + | - | - |
| Killdeer (*Charadrius vociferus*) | (B,R) | + | + | + | + | + | + |
| Long-billed curlew (*Numenius americanus*) | (F,M) | + | + | + | + | + | + |
| Spotted sandpiper (*Actitis macularia*) | (B,W) | - | + | - | - | - | - |
| Willet (*Catoptrophorus semipalmatus*) | (B,R) | + | + | + | + | + | + |
| Greater yellowlegs (*Totanus melanoleucus*) | (B,W) | - | - | - | - | - | + |
| Ruddy turnstone (*Arenaria interpres*) | (B,R) | + | + | - | - | + | + |
| Pectoral sandpiper (*Erolia melanotos*) | (B,M) | - | - | + | - | + | + |
| Dunlin (*Erolia alpina*) | (B,M) | - | - | + | + | + | - |
| Knot (*Calidris canutus*) | (B,M) | - | - | - | - | + | - |
| Sanderling (*Crocethia alba*) | (B,M) | - | + | + | + | + | + |

Table 14 (CONTINUED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| White-rumped sandpiper (*Erolia fuscicollis*) | (F,M) | - | + | - | - | - | - |
| Least sandpiper (*Erolia minutilla*) | (B,M) | + | + | + | - | + | - |
| Semipalmated sandpiper (*Ereunetes pusillus*) | (B,M) | - | + | + | + | + | + |
| Herring gull (*Larus argentatus*) | (F,W) | + | - | + | + | + | + |
| Ring-billed gull (*Larus delawarensis*) | (F,R) | - | + | - | + | + | + |
| Laughing gull (*Larus atricilla*) | (B,R) | + | + | + | + | + | + |
| Least tern (*Sterna albifrons*) | (F,R)* | + | + | - | - | - | + |
| Common tern (*Sterna hirundo*) | (F,R) | + | + | + | + | + | + |
| Forster's tern (*Sterna forsteri*) | (B,M) | - | - | - | - | - | + |
| Gull-billed tern (*Gelochelidon nilotica*) | (B,R) | + | - | - | - | + | + |
| Royal tern (*Thalasseus maximus*) | (F,R) | - | - | + | + | + | + |
| Caspian tern (*Hydroprogne caspia*) | (B,R) | + | + | + | + | + | + |
| Black tern (*Childonias niger*) | (F,M) | + | + | + | - | - | - |
| Black skimmer (*Rynchops niger*) | (F,R) | + | + | + | - | - | - |
| Mourning dove (*Zenaida macroura*) | (P,R) | + | + | + | + | + | + |

Table 14 (CONTINUED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Yellow-billed cuckoo (Coccyzus americanus) | (P,M) | + | + | + | - | - | - |
| Common nighthawk (Chordeiles minor) | (P,M) | + | + | + | + | - | - |
| Ruby-throated hummingbird (Archilochus colubris) | (F,M) | - | + | - | - | - | - |
| Scissor-tailed flycatcher (Muscivora forficata) | (P,M) | + | + | + | + | - | - |
| Eastern kingbird (Tyrannus tyrannus) | (P,M) | + | + | + | - | - | - |
| Great crested flycatcher (Myiarchus crinitus) | (P,M) | - | + | - | - | - | - |
| Eastern phoebe (Sayornis phoebe) | (P,R) | - | + | - | - | - | - |
| Barn swallow (Hirundo rustica) | (F,M) | + | + | + | + | + | - |
| Rough-winged swallow (Stelgidopteryx ruficollis) | (F,R) | - | + | + | + | + | - |
| Purple martin (Progne subis) | (F,M) | + | - | - | - | - | - |
| Common crow (Corvus brachyrhynchos) | (F,R) | - | - | + | - | - | - |
| Short-billed marsh wren (Cistothorus platensis) | (P,W) | - | - | - | + | + | + |
| Mockingbird (Mimus polyglottos) | (P,R) | + | - | - | - | - | - |
| Brown thrasher (Toxostoma rufum) | (P,R) | - | - | + | - | - | - |
| Robin (Turdus migratorius) | (P,W) | - | - | + | - | - | - |

Table 14 (CONTINUED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Veery (*Hylocichla fuscesens*) | (P,M) | - | - | - | - | - | + |
| Blue-gray gnatcatcher (*Polioptila caerulea*) | (P,R) | - | - | + | + | - | - |
| Ruby-crowned kinglet (*Regulus calendula*) | (P,W) | - | - | + | - | - | - |
| Water pipit (*Anthus spinoletta*) | (B,W) | - | - | - | - | - | + |
| Sprague's pipit (*Anthus spragueii*) | (B,W) | - | - | - | - | - | + |
| Cedar waxwing (*Bombycilla cedrorum*) | (P,W) | - | - | + | - | - | - |
| Loggerhead shrike (*Lanius ludovicianus*) | (P,R) | - | - | + | + | + | + |
| White-eyed vireo (*Vireo griseus*) | (P,R) | - | - | - | - | - | + |
| Orange-crowned warbler (*Vermivora celata*) | (P,W) | - | - | - | + | - | - |
| Louisiana waterthrush (*Seiurus motacilla*) | (B,M) | - | - | + | - | - | - |
| Eastern meadowlark (*Sturnella magna*) | (P,R) | + | + | + | + | + | + |
| Red-winged blackbird (*Agelaius phoeniceus*) | (P,R) | + | + | + | - | + | + |
| Boat-tailed grackle (*Cassidix mexicanus*) | (P,R) | + | + | + | - | - | - |
| Common grackle (*Quiscalus quiscula*) | (P,R) | + | + | - | + | - | - |
| Brown-headed cowbird (*Molothrus ater*) | (P,R) | + | + | + | - | - | - |

Table 14 (CONCLUDED)

| Common Name (Scientific name) | | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| Orchard oriole (*Icterus spurius*) | (P,M) | + | + | + | - | - | - |
| Baltimore oriole (*Icterus galbula*) | (P,M) | - | - | + | - | - | - |
| Blue grosbeak (*Guiraca caerulea*) | (P,M) | - | - | + | - | - | - |
| Savannah sparrow (*Passerculus sandwichensis*) | (P,W) | - | - | - | - | + | + |
| Grasshopper sparrow (*Ammodramus savannarum*) | (P,W) | - | - | - | - | - | + |
| Le Conte's sparrow (*Passerherbulus caudacutus*) | (P,W) | - | - | + | - | - | + |
| Seaside sparrow (*Ammospiza maritima*) | (P,R) | - | - | + | - | - | + |
| Vesper sparrow (*Pooecetes gramineus*) | (P,W) | - | - | - | - | + | + |
| Chipping sparrow (*Spizella passerina*) | (P,W) | - | - | - | + | - | - |
| Field sparrow (*Spizella pusilla*) | (P,W) | - | - | - | - | - | + |
| Swamp sparrow (*Melospiza georgiana*) | (P,W) | - | - | - | + | - | + |
| Song sparrow (*Melospiza melodia*) | (P,W) | - | - | - | + | + | + |
| TOTALS | | 41 | 43 | 50 | 37 | 43 | 45 |

Table 15

Mammals Captured or Seen on the Bolivar Peninsula Study Site

| Species | Common Name | Abundance* |
|---|---|---|
| *Didelphis marsupialis* | opossum | r |
| *Blarina brevicauda* | short-tailed shrew | r |
| *Procyon lotor* | raccoon | vc |
| *Spilogale putorius* | spotted skunk | r |
| *Myocastor coypus* | nutria | r |
| *Mus musculus* | house mouse | c |
| *Sigmodon hispidus* | cotton rat | vc |
| *Sylvilagus aquaticus* | swamp rabbit | c |
| *Sylvilagus floridanus* | cottontail rabbit | r |
| *Dasypus novemcinctus* | armadillo | vc |
| *Capra hircus* | goat | vc |
| *Bos indicus* | cow | c |
| *Ovis aries* | sheep | c |

*r = rare, seen only once; c = common, seen occasionally; vc = very common, seen or captured every visit.

Table 16

Population Estimates of Small Mammals on the Study Site, 1975

| Species | Population per Hectare | | |
|---|---|---|---|
| | Oct. | Nov. | Dec. |
| *Sigmodon hispidus* | 25.3 | 35.3 | 29.1 |
| *Mus musculus* | * | 1.6 | 10.2 |

* Population too low to estimate

(juveniles) do not enter traps as readily as socially dominant (adult) individuals.

62. Most of the rats were collected from the Spartina patens and Andropogon communities. These apparently provided adequate protection in the form of cover.

63. The house mouse was not trapped in sufficient numbers to estimate its popula  on until November. In December, trapped animals were 73.3% male and 26.7% female.

64. The Monarda community supported the largest house mouse population, with Spartina second. Sesbania-mixed grass supported the lowest. Vegetative community use by the house mouse was thus opposite that by the cotton rat.

65. The number of other mammals captured or seen was small and no population estimates were made. Eighteen raccoons were collected from the study site and moved to the mainland to reduce interference with the small mammal survey. Rabbits were abundant, estimated to be at least one per hectare, based on periodic sighting and scats. Nutria were seen in the marsh, and skunks and armadillo in all vegetation types.

66. Normal mammal species numbers on the mainland adjacent to Galveston Bay are 15-16. High m  ers, such as fou  in a refuge, would be 22. This study site's ten is comparatively low.

67. Herptiles. The diversity of reptiles and amphibians on the study site was low with only 11 species sighted (Table 17). Eight of these feed on insects and two (cottonmouth and kingsna  ) feed o  mammals and birds. The salt marsh snake also feeds on crabs and crayfish. Population estimates of reptiles and amphibians were not made due to the low numbers observed.

68. Macroinvertebrates. The macroinvertebrate fauna was samp ed from the edge of Galveston Bay to the GIWW. Population estimates of only a few forms were made since the techniques used did not allow for collection of quantitative data for all groups. Other species were reported as observed (Table 18). Species represented are considered similar to those in other sections of Galveston Bay.

Table 17

Amphibians and Reptiles Observed on the Bolivar Peninsula Study Site

| Species | Common name | Number of Observations |
|---|---|---|
| *Bufo valliceps* | gulf coast toad | 7 |
| *Gastrophryne carolinensis* | narrow-mouth frog | 1 |
| *Eumeces* sp. | skink | 1 |
| *Cnemidophorus sexlineatus* | six-lined racerunner | 5 |
| *Phrynosoma cornutum* | Texas horned lizard | 3 |
| *Ophisaurus attenuatus* | glass lizard | 2 |
| *Terrapene ornata ornata* | ornate box turtle | 4 |
| *Thamnophis sirtalis sirtalis* | eastern garter snake | 1 |
| *Natrix fasciata clarki* | salt marsh snake | 5 |
| *Agkistrodon piscivorus* | cottonmouth | 2 |
| *Lampropeltis getulus holbrooki* | speckled kingsnake | 1 |

Table 18

Macroinvertebrate Fauna of the Bolivar Peninsula Study Site

| ORDER | FAMILY SPECIES | COMMON NAME | POPULATION ($M^2$) |
|---|---|---|---|
| CAPITELLIDA | CAPITELLIDAE | polychaeta | |
| | Mediomastus californiensis | | 18.0 |
| PHYLLODOCIDA | EUNICIDAE | polychaeta | |
| | Diopatra cuprea | | 9.0 |
| | 2 species | unidentified | 6.0 |
| | Succinea ovalis | land snail | 2.0 |
| | Succinea sp. | land snail | 4.0 |
| | Mesomphyx sp. | land snail | 0.5 |
| | Zonitoides sp. | land snail | 0.1 |
| LABIDOGNATHA | DYSDERIDAE | dysderids spiders | 0.5 |
| | LOXOSCELIDAE | brown spiders | 1.0 |
| | THERIDIIDAE | cobweb spiders | 0.1 |
| | LINYPHIIDAE | dwarf spiders | 2.0 |
| | ARANEIDAE | orb-weavers | 1.0 |
| | TETRAGNATHIDAE | | 0.1 |
| | LYCOSIDAE | wolf spiders | 0.2 |
| | THOMISIDAE | crab spiders | 0.2 |
| | SALTIDIDAE | jumping spiders | 0.2 |
| SCORPIONES | BUTHIDAE | centruroides | 0.1 |
| ACARINA | IXODIDAE | | |
| | Amblyomma americanum | tick | 4.0 |
| ISOPODA | ARMADILLIDIIDAE | pill bug | 0.2 |
| DECAPODA | PAGURIDAE | | |
| | Pagurus sp. | hermit crab | - |
| | OCYPODIDAE | | |
| | Ocypode quadrata | ghost crab | - |
| | Uca pugnax | mud fiddler | 21.0 |
| ODONATA | AESHNIDAE | | |
| | Aeshna sp. | darners | - |
| | LIBELLULIDAE | | |
| | Sympetrum sp. | skimmers | 0.1 |
| | COENAGRIONIDAE | | |
| | Enallagma | damselflies | 0.1 |
| ORTHOPTERA | ACRIDIDAE | short-horned grasshopper | 6.0 |
| | TETRIGIDAE | pygmy grasshopper | - |
| | TETTIGONIIDAE | long-horned grass-hopper | - |
| | GRYLLIDAE | ground cricket | 2.0 |

Table 18 (CONTINUED)

| ORDER | FAMILY SPECIES | COMMON NAME | POPULATION ($M^2$) |
|---|---|---|---|
| | PHASMATIDAE | walking stick | 0.1 |
| | MANTIDAE | mantid | 0.1 |
| | BLATTIDAE | cockroach | |
| | BLATTELLIDAE | woodroach | |
| DERMAPTERA | LABIDURIDAE | | |
| | *Labidura* sp. | earwig | 1.0 |
| HEMIPTERA | BELOSTOMATIDAE | water bug | - |
| | PENTATOMIDAE | stink bug | 1.0 |
| | REDUVIIDAE | assassin bug | - |
| | LYGAEIDAE | seed bug | - |
| | LARGIDAE | largid bug | - |
| | CYDNIDAE | burrower bug | - |
| | MIRIDAE | plant bug | 2.0 |
| HOMOPTERA | CICADIDAE | cicadas | 1.0 |
| | CICADELLIDAE | leafhoppers | 3.0 |
| | FULGOROIDAE | planthoppers | - |
| | APHIDIDAE | aphids | - |
| | DIASPIDIDAE | scales | - |
| COLEOPTERA | CICINDELIDAE | tiger beetles | 6.0 |
| | CARABIDAE | ground beetles | 2.0 |
| | STAPHYLINIDAE | rove beetles | 1.0 |
| | LAMPHYRIDAE | fireflies | 1.0 |
| | DERMESTIDAE | dermistids | - |
| | MELYRIDAE | flower beetles | - |
| | CLERIDAE | checkered beetles | - |
| | ELATERIDAE | click beetles | - |
| | BUPRESTIDAE | wood-boring beetles | - |
| | DASCILLIDAE | soft-bodied plant | - |
| | CUCUJIDAE | flat bark beetles | 1.0 |
| | COCCINELLIDAE | ladybird beetles | 2.0 |
| | CEPHALOIDAE | false longhorn beetles | - |
| | MELOIDAE | blister beetles | 1.0 |
| | TENEBRIONIDAE | darkling beetles | 2.0 |
| | ANOBIIDAE | anobids | - |
| | LUCANIDAE | stag beetles | - |
| | SCARABAEIDAE | scarab beetles | 3.0 |
| | CERAMBYCIDAE | long-horned beetles | 2.0 |
| | CHRYSOMELIDAE | leaf beetles | 1.0 |
| | CURCULIONIDAE | snout beetles | 1.0 |
| | RHYNCHOPHORIDAE | grain weevils | 1.0 |
| NEUROPTERA | CORYDALIDAE | dobsonflies | - |
| | CHRYSOPIDAE | lacewings | - |
| | MYRMELEONTIDAE | antlions | - |

Table 18 (CONCLUDED)

| ORDER | FAMILY SPECIES | COMMON NAME | POPULATION ($M^2$) |
|---|---|---|---|
| TRICHOPTERA | PHRYGANEIDAE | large caddisflies | - |
| | LIMNEPHILIDAE | northern caddisflies | - |
| LEPIDOPTERA | PAPILIONIDAE | swallowtails | - |
| | PIERIDAE | sulphurs | - |
| | DANAIDAE | milkweed | - |
| | HELICONIIDAE | heliconiana | - |
| | SPHINGIDAE | sphinx | - |
| | ARCTIIDAE | tiger mot' | - |
| | LASIOCAMPIDAE | tent caterpillars | - |
| | GEOMETRIDAE | geometers | - |
| | GELECHIIDAE | grain moths | - |
| | PSYCHIDAE | bagworm moths | - |
| DIPTERA | TIPULIDAE | crane flies | - |
| | PSYCHODIDAE | sand flies | - |
| | CHAOBORIDAE | plantom midges | - |
| | CULICIDAE | mosquitoes | - |
| | CERATOPOGONIDAE | biting midges | - |
| | TABANIDAE | horse flies | - |
| | ASILIDAE | robber flies | 1.0 |
| | SCIOMYIDAE | marsh flies | 1.0 |
| | MUSCIDAE | house flies | - |
| HYMENOPTERA | ICHNEUMONIDAE | ichneumons | - |
| | TIPHIIDAE | tiphids | - |
| | MUTILLIDAE | velvet ants | - |
| | FORMICIDAE | ants | 100+ |
| | APIDAE | bees | - |

69. The most common invertebrates were grasshoppers and land snails. The mud fiddler crab was very numerous (Table 18) in the restricted habitat occupied (i.e. mud areas around freshwater marshes). Ghost crabs were numerous along the bay shore as were tiger beetles in the summer months.

70. Polychaeta were numerous ($181/m^2$) in the beach soil within the top six inches of the surface. Other larvae (Insecta) were also found in this area and numbered as high as $60/m^2$ in the summer months.

# PART VI: SEDIMENT CHEMISTRY

71. Baseline information regarding the soils and sediments presently located in the proposed study site was collected in this phase of the study. The information collected will determine the chemical and physical characteristics of the sediments prior to proposed dredging and disposal operations on the site.

72. Sediment and soil samples were analyzed to determine those agronomic properties that were considered important to the establishment of marsh vegetation. Potential pollution and toxic characteristics of the materials were also examined.

## Methods

73. Nine sediment cores were taken along three of the random transect lines in the study site. Sediment cores were taken with a stainless steel coring device fitted with a PVC liner. The PVC liners were cleaned with nitric acid and thoroughly rinsed with distilled water prior to use to prevent contamination of the sediment sample. Also, each liner was precut to the proper length, then taped prior to insertion into the coring device. Each core was about 110 cm in length.

74. Immediately after the core was taken, the plastic liner was extruded from the core barrel into a large glove bag that had been purged with nitrogen ($N_2$) gas. The core sections were separated (10-cm top section, and successive 25-cm lower sections) and each end of the section capped while it was in the glove bag. Core sections were then transported to the laboratory for further analyses.

75. Each core section was extruded from the PVC liner in the laboratory under a nitrogen atmosphere. The Eh and pH measurements were made in the glove bag to prevent oxidation of the core. A small portion of each core section was sealed under a nitrogen atmosphere in a plastic vial to be used for sulfide analysis.

76. The cores were removed from the glove bag. Half of each core section was used for soil classification, and the other half was stored at $4^{o}$ C for subsequent analyses.

77. Interstitial water samples were taken in the field from the sediments in situ. PVC pipes, 6 inches in diameter and 4 feet long, were driven into the ground. The sediment was removed from the inside of the PVC pipe. Plastic gas dispersion tubes were fitted through holes drilled

in the wall of the PVC pipe so that the porous ends of the dispersion tubes were sticking into the sediment. Plastic vials were attached to the dispersion tubes, and a partial vacuum was applied to pull the interstitial water from the sediments (Figure 3). When full, the plastic vials were removed, and the interstitial pore water collected was acidified with hydrochloric acid (HCl). The plastic vials were then sealed and stored at 4°C prior to interstitial water analysis.

Total core analysis

78. Eh and pH. Measurements of these two parameters were made in an oxygen-free atmosphere. The Eh measurements were made with a shiny platinum electrode and a calomel half-cell as reference; pH measurements were made with a standard glass electrode and calomel half-cell. The electrodes were placed in the center of each core section prior to Eh and pH measurement.

79. Total sulfide (Beaton and Burns 1968). A sediment sample was placed in a Kjeldahl flask and mixed with distilled water. The sample was boiled under a nitrogen atmosphere while HCl was being added. The hydrogen sulfide ($H_2S$) evolved was trapped in a cadmium-zinc acetate solution. Excess iodine solution was added along with HCl. The excess iodine was back-titrated with standard sodium thiosulphate solution. Results are reported in units of milligrams per kilogram of wet sediment.

80. Particle-size distribution (Day 1965). Percent sand (> 53μ), silt (2-53μ), and clay (< 2μ) were determined for each section by the sieve-pipette method.

81. Total organic matter (Allison 1965). Readily oxidizable organic matter in the sediment sample was oxidized by dichromate ion ($Cr_2O_7^{-2}$) in the presence of sulfuric acid ($H_2SO_4$). The excess $Cr_2O_7^{-2}$ was determined by titration with a standard ferrous sulphate ($FeSO_4$) solution. The quantity of organic matter oxidized was calculated from the amount of $Cr_2O_7^{-2}$ reduced. All results are reported as percent organic matter in the dry sediment.

82. Total organic nitrogen (Bremner 1965a). A sediment sample was placed into a 100-ml micro-kjeldahl flask. A potassium sulfate ($K_2SO_4$) catalyst mixture was added to the flask along with concentrated sulfuric acid ($H_2SO_4$). The flask was boiled until the sediment sample was properly

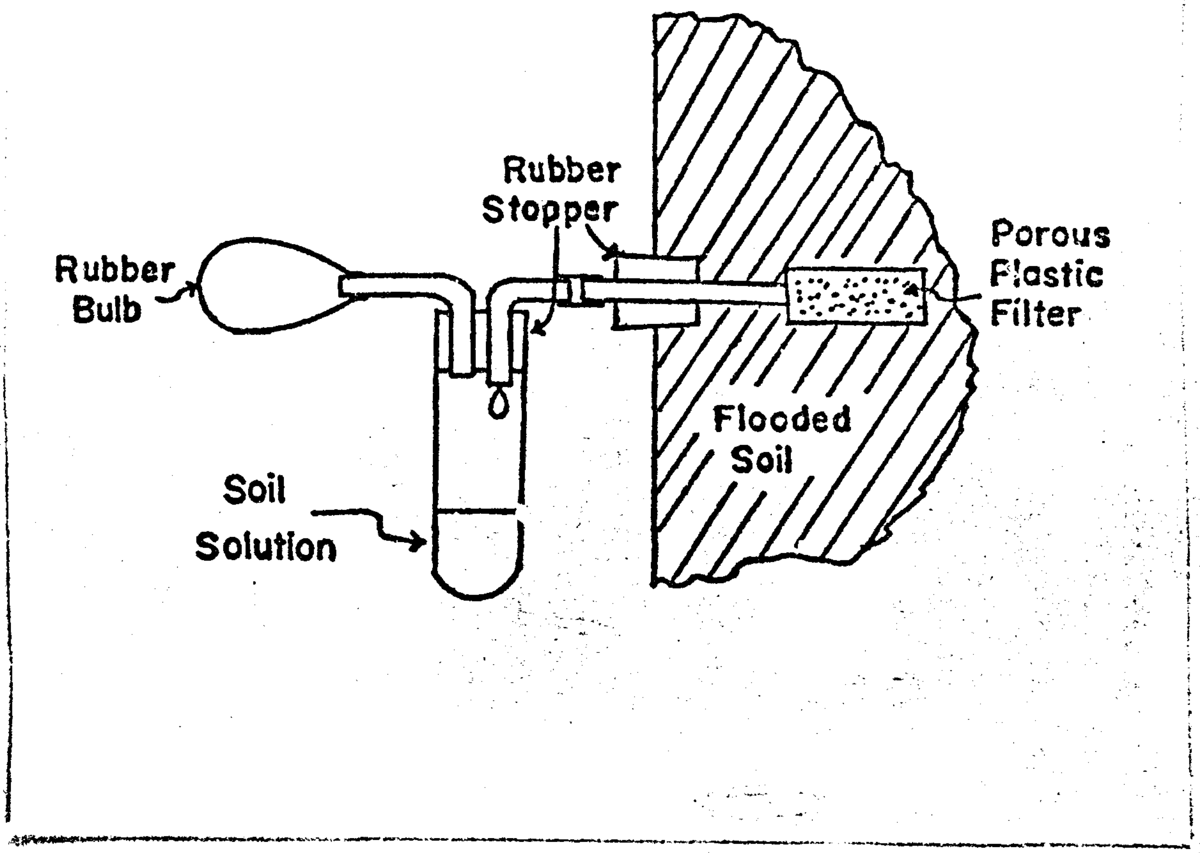


Figure 3. Method used for sampling of interstitial pore water in the field

digested. The total organic nitrogen present was determined by steam distillation of ammonia utilizing a boric acid ($H_3BO_3$) indicator solution. Data will be reported as milligrams of nitrogen per kilogram of dry sediment.

83. Ammonium (Bremner 1965b). Exchangeable ammonium was extracted with a 2-N potassium chloride (KCl) solution and the ammonium-N($NH_4^+$-N) determined by steam distillation. Data will be reported as milligrams of nitrogen per kilogram of dry sediment.

84. Cation exchange capacity (Keeney and Bremner 1969). The cation exchange capacity was determined by treating the sediment sample with 1-N ammonium acetate ($NH_4OA$) (pH 7.0), after which $NH_4OA$ was removed by leaching with an ammonium nitrate ($NH_4NO_3$) solution. The treated sample was analyzed for $NH_4^+$-N and $NO_3^-$-N by steam distillation methods. Data will be reported as milliequivalents per 100 g of sediment.

85. Extractable orthophosphate (Watanabe and Olsen 1965). Orthophosphate was extracted from the sediment sample with distilled water ($H_2O$). Ammonium molybdate-antimony potassium tartrate and ascorbic acid reagents were added. The extractable orthophosphate was then determined by the intensity of the blue color produced. The results will be reported as milligrams of phosphorus per liter of solution.

86. Metals (atomic absorption methods) (U.S. Environmental Protection Agency (EPA) 1974). A sediment sample was completely dissolved using hydrofluoric acid (HF), nitric acid ($HNO_3$), and perchloric acid ($HClO_4$). The metals released were determined by flame and flameless atomic absorption methods. The results will be reported as micrograms of metal per gram of sediment.

Interstitial water analysis

87. Nitrate-N (U.S. Environmental Protection Agency (EPA) 1974). Nitrate-N was reduced to nitrite with cadmium-copper (Cd-Cu) catalyst. The nitrites (those originally present plus reduced nitrates) were reacted with sulfanilamide to form a diazo compound which was then coupled with N-(1 napthyl-ethylenediamine hydrochloride) at pH 2.0 to form the azo dye. The azo dye intensity, which was proportional to the nitrate concentration, was then measured. Separate rather than combined nitrate-nitrite values were readily obtainable by carrying out the procedure first with and then without the initial Cd-Cu reduction step.

Data will be reported as milligrams per liter of nitrate-N.

88. Nitrite-N (U.S. Environmental Protection Agency (EPA) 1974). A diazonium compound formed by diazotization of sulfanilamide by nitrite in water under acid conditions was coupled with N-(1-naphthyl)-ethylenediamine to produce a reddish-purple color, the intensity of which was then measured. Data will be reported as milligrams per litre of nitrite-N.

89. Ammonium-N (U.S. Environmental Protection Agency (EPA) 1974). This distillation method can be used to measure ammonium-N exclusive of total Kjeldahl nitrogen in surface waters, domestic and industrial wastes, and saline waters.

90. The sample was buffered at a pH of 9.5 with a borate buffer to decrease hydrolysis of cyanates and organic nitrogen compounds. It was then distilled into a solution of boric acid. The ammonia in the distillate was determined titrimetrically with standard $H_2SO_4$ and a mixed indicator. The results will be reported as milligrams per litre of ammonium-N.

91. Total Kjeldahl nitrogen (U.S. Environmental Protection Agency (EPA) 1974). he sample was heated in the presence of concentrated sulfuric acid ($H_2SO_4$), potassium sulfate ($K_2SO_4$), and magnesium sulfate ($MgSO_4$), and then evaporated until sulfur trioxide ($SO_3$) fumes were obtained and the solution became colorless or pale yellow. The residue was cooled, diluted, and made alkaline with a hydroxidithiosulfate solution. The ammonium was determined titrimetrically after distillation.

92. Total phosphorus and orthophosphate (U.S. Environmental Protection Agency A) 1974). The method is based on reactions that are specific for the orthophosphate ion. The methods are applicable to the range of 0.01- [illegible] milligrams per liter of phosphorus.

93. Ammonium molybdate and potassium antimony tartrate were reacted with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex. This complex becomes an intense blue when ascorbic acid is added. The color, which is proportional to the orthophosphate concentration, was then measured. The data will be reported as milligrams per litre.

94. Dissolved organic carbon (U.S. Environmental Protection Agency (EPA) 1974). Five ml of filtered interstitial water, 0.25 ml of 6 percent

phosphoric acid ($H_3PO_4$), and 0.2 g of potassium persulfate ($K_2S_2O_8$) were placed in a 10-ml glass ampule. Hot oxygen ($O_2$) gas was bubbled through the sample, and after 6 minutes the ampule was sealed with a flame. The sealed ampules were placed overnight in an oven at 110° centigrade (C) to convert the organic carbon to carbon dioxide ($CO_2$). The evolved $CO_2$ was measured by an infrared detector. The results will be reported as milligrams of carbon per litre.

95. Metals (atomic absorption methods) (U.S. Environmental Protection Agency (EPA) 1974). Metals in solution were determined by atomic absorption spectroscopy. A Perkin-Elmer model 403 atomic absorption spectrophotometer was used. The results will be reported as micrograms of metal per millilitre of solution.

## Results

96. Nine separate locations were chosen from which core samples to a depth of 107 cm would be taken (Figure 4). The locations were chosen to coincide with and transect the major vegetation types on the Bolivar site. Three core samples were taken from an upland location where oxidized conditions would be expected to exist throughout the profile. Intermediate locations were chosen to include sites where the profile was generally oxidized in the surface but reduced in the lower profile and where a free water table might exist. The last three locations were in the intertidal area and were saturated with water at all times.

97. Initially, six profiles (cores 1-6) were sampled and transported to the laboratory. Attempts were made to extract sufficient interstitial water to perform chemical analysis. However, due to the low total water content of the sediments and low compressibility, it was not possible to extract enough water by centrifugation or by compression for analysis. It was then decided to extract interstitial water in the field. The remaining three cores (7-9) and the interstitial water samples were taken about a week later. Due to the large volume of interstitial water needed for all chemical analysis, an additional set of water samples were pulled about a week after the first set of interstitial water samples were taken. Because of the problems involved in obtaining interstitial water samples, some care must be taken when comparing interstitial water analyses to corresponding core analyses. Interstitial water samples and

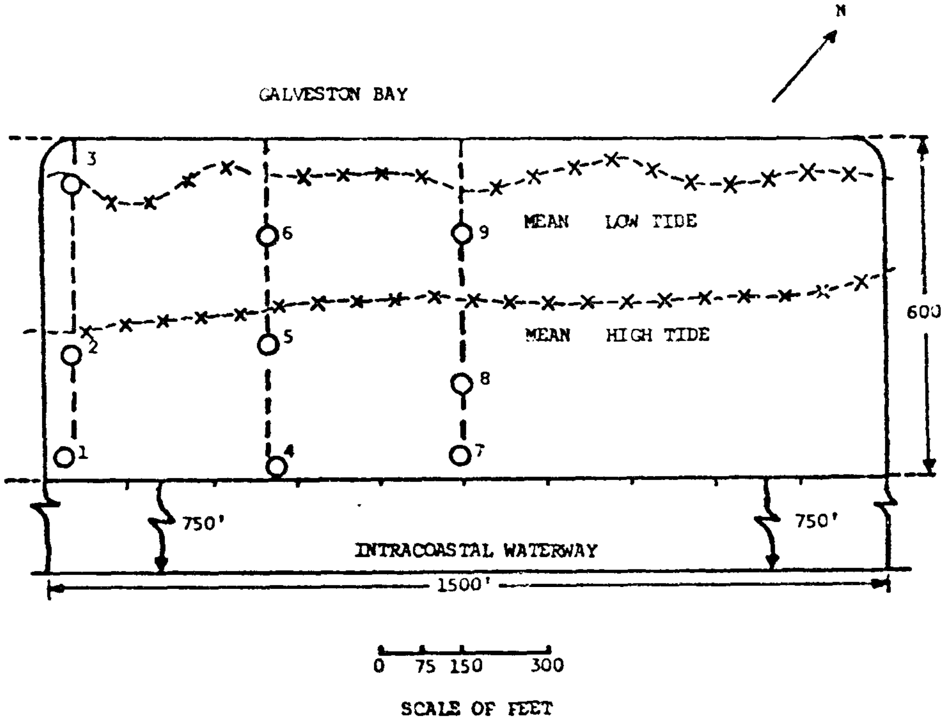


Figure 4. Bolivar Peninsula experimental site with locations of nir core samples taken for chemical and physical analysis

core samples were pulled at different times and, in some cases, from slightly different locations.

98. Sediment samples taken to a depth of 107 cm were all sandy in texture. There was some variation with depth in terms of texture, color, and organic matter. There were also some pockets of shells, silt, and clay. Complete core descriptions are given in Appendix B'.

Upland sites

99. Cores were taken near the baseline and numbered as cores 1, 4, and 7. Data for core 1 are given in Tables 19 and 20, core 4 in Tables 21 and 22, and core 7 in Tables 23 and 24. For these sites there was inadequate soil moisture for interstitial water samples.

100. Color, as determined from the Munsel color charts, was consistent for the three sites. The normal reading was 10 YR 5/2 throughout most of each profile.

101. Moisture content of the cores varied, primarily because of the time of sampling. Cores 1 and 4 were taken prior to and core 7 was taken following a rainy period. The primary difference was the high moisture content throughout the profile of core 7. Core 7 also had a lower Eh value in the lower section of the profile.

102. Textural analysis of the cores shows that the profiles are sand to a depth of 107 cm. Sand content of the sediments ranged from 88.4 to 98.97 percent. Clay content ranged from 0 to 5.00 percent. However, in most profiles the clay content was less than 2 percent.

103. Eh values generally reflected the moisture content of the profiles. The lower the moisture content, the higher the redox potential of the core section. pH values were all above neutrality. Individual horizon values ranged from a low of 7.10 to a high of 8.40.

104. Total organic nitrogen and organic carbon were closely related. As the organic carbon increased from 0.04 to 0.36 percent, the organic nitrogen also increased from 21 to 202 mg/kg.

105. Exchangeable ammonium ($NH_4^+$) was generally low (< 0.30 mg/kg). Core 7, which was taken after a tropical storm had moved through the area, had consistently high amounts of exchangeable $NH_4^+$. Water-extractable orthophosphate was relatively high with most values over 0.10 mg/kg. Values ranged from a low of 0.042 to 0.741 mg/kg.

Table 12

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 1, an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) | | | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sand | Silt | Clay | | | | | | |
| 0-10 | 10 YR 5/2 | 4.80 | 98.97 | 1.25 | 0.00 | +492 | 7.10 | 0.12 | 52.0 | <0.30 | 0.333 |
| 10-35 | 10 YR 6/2 | 4.50 | 96.97 | 1.25 | 1.25 | +471 | 7.40 | 0.13 | 29.9 | <0.30 | 0.208 |
| 35-60 | 10 YR 5/2 | 2.47 | 96.00 | 2.50 | 1.25 | +491 | 7.25 | 0.16 | 43.8 | <0.30 | 0.167 |
| 60-85 | 10 YR 5/2 | 13.20 | 88.40 | 6.25 | 5.00 | +456 | 8.40 | 0.18 | 70.5 | <0.30 | 0.150 |
| 85-107 | 10 YR 4/1 | 11.20 | 95.99 | 2.50 | 1.25 | +461 | 8.25 | 0.28 | 95.1 | 0.36 | 0.175 |

Table 20

Chemical Analyses of Sediments Taken at Various Depths at Location 1, an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Calcium (μg/g) | Potassium (μg/g) | Sodium (μg/g) | Magnesium (μg/g) | Iron (μg/g) | Manganese (μg/g) | Zinc (μg/g) | Copper (μg/g) | Lead (μg/g) | Cadmium (μg/g) | Mercury (μg/g) | Sulfide (μg/g) | Cat Exch Capac (meq/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 8,290 | 2,860 | 3,010 | 710 | 3,560 | 122 | 12.6 | 10.0 | 8.6 | 0.70 | 0.05 | 1.00 | 0.95 |
| 10-35 | 9,660 | 4,980 | 3,120 | 810 | 4,030 | 135 | 14.7 | 15.9 | 11.0 | 0.70 | 0.05 | 0.62 | 1.10 |
| 35-60 | 8,390 | 4,720 | 3,570 | 990 | 4,750 | 111 | 16.5 | 13.1 | 10.2 | 0.70 | 0.08 | <0.58 | 1.53 |
| 60-85 | 7,360 | 3,360 | 4,480 | 1,570 | 6,410 | 164 | 21.4 | 21.4 | 13.3 | 0.82 | 0.06 | <0.58 | 3.40 |
| 85-107 | 37,410 | 5,700 | 3,150 | 1,250 | 5,200 | 276 | 16.8 | 11.7 | 12.0 | 1.36 | 0.05 | <0.58 | 2.40 |

Table [illegible]

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 4,

an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 5/2 | 6.5 | 96.15 | 2.50 | 1.25 | +476 | 7.80 | 0.36 | 202.6 | <0.30 | 0.042 |
| 10-35 | 10 YR 5/2 | 9.7 | 97.55 | 1.25 | 1.25 | +486 | 8.05 | 0.06 | 43.1 | <0.30 | 0.066 |
| 35-60 | 10 YR 5/1 | 17.2 | 96.72 | 2.50 | 1.25 | +331 | 7.90 | 0.12 | 86.2 | <0.30 | 0.233 |
| 60-85 | 10 YR 5/2 | 18.4 | 98.28 | 1.25 | 0.00 | +286 | 8.00 | 0.09 | 48.4 | <0.30 | 0.233 |
| 85-107 | 10 YR 5/2 & 10 YR 4/3 | 19.0 | 97.60 | 1.25 | 0.00 | +136 | 7.90 | 0.04 | 25.3 | <0.30 | 0.292 |

Table [illegible]

Chemical Analyses of Sediments Taken at Various Depths at Location 4, an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Calcium (µg/g) | Potassium (µg/g) | Sodium (µg/g) | Magnesium (µg/g) | Iron (µg/g) | Manganese (µg/g) | Zinc (µg/g) | Copper (µg/g) | Lead (µg/g) | Cadmium (µg/g) | Mercury (µg/g) | Sulfide (µg/g) | Cation Exchange Capacity (meq/100g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10,190 | 5,590 | 2,920 | 720 | 3,790 | 120 | 13.3 | 9.8 | 8.9 | 0.70 | 0.04 | 1.26 | 0.41 |
| 10-35 | 3,210 | 3,490 | 1,680 | 390 | 2,070 | 61 | 8.6 | 22.7 | 3.9 | 0.41 | 0.05 | <0.58 | 0.77 |
| 35-60 | 8,540 | 7,080 | 3,680 | 920 | 4,440 | 75 | 19.5 | 27.2 | 11.7 | 0.76 | 0.02 | <0.67 | 0.23 |
| 60-85 | 3,970 | 3,870 | 2,990 | 740 | 3,640 | 85 | 13.6 | 13.7 | 9.0 | 0.70 | 0.04 | <0.58 | 0.20 |
| 85-107 | 6,700 | 7,470 | 3,490 | 830 | 4,480 | 115 | 15.2 | 12.9 | 9.8 | 0.76 | 0.02 | <0.58 | 0.08 |

Table 25

Chemical and Physical Analyses of Sediments Taken at Various Depths at Location 7, an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Orgaric Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 5/2 | 14.7 | 95.77 | 2.50 | 2.50 | +406 | 7.40 | 0.10 | 47.0 | 1.42 | 0.092 |
| 10-35 | 10 YR 5/2 | 18.7 | 98.29 | 0.00 | 1.25 | +396 | 7.40 | 0.19 | 66.2 | 0.36 | 0.125 |
| 35-60 | 10 YR 5/2 | 17.7 | 99.46 | 0.00 | 1.25 | +391 | 7.35 | 0.10 | 21.0 | 1.78 | 0.100 |
| 60-85 | 10 YR 5/2 | 19.7 | 96.27 | 3.73 | 0.00 | +141 | 7.40 | 0.12 | 113.6 | 1.07 | 0.416 |
| 85-107 | 10 YR 5/2 | 19.5 | 94.99 | 1.25 | 1.[illegible] | -34 | 7.35 | 0.16 | 94.0 | 1.42 | 0.741 |

Table 24

Chemical Analyses of Sediments Taken at Various Depths at Location 7, an Upland Location from Bolivar Peninsula Study Site

| Core Section (cm) | Calcium (µg/g) | Potassium (µg/g) | Sodium (µg/g) | Magnesium (µg/g) | Iron (µg/g) | Manganese (µg/g) | Zinc (µg/g) | Copper (µg/g) | Lead (µg/g) | Cadmium (µg/g) | Mercury (µg/g) | Sulfide (µg/g) | Catio[illegible] Exchan[illegible] Capaci[illegible] (meq/1[illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 7,010 | 4,980 | 2,990 | 650 | 3,180 | 102 | 15.4 | 43.6 | 19.2 | 0.70 | 0.05 | <0.58 | 0.9[illegible] |
| 10-35 | 7,780 | 3,730 | 2,990 | 730 | 3,490 | 120 | 14.9 | 16.5 | 10.2 | 0.70 | 0.02 | <0.58 | 1.[illegible] |
| 35-60 | 6,680 | 4,720 | 2,860 | 610 | 3,060 | 100 | 13.8 | 16.0 | 10.2 | 0.68 | 0.05 | <0.58 | 0.9[illegible] |
| 60-85 | 6,530 | 7,840 | 3,920 | 1,120 | 8,190 | 135 | 17.8 | 16.1 | 11.3 | 0.76 | 0.04 | <0.58 | 1.7[illegible] |
| 85-107 | 11,280 | 5,880 | 4,410 | 1,790 | 6,080 | 152 | 20.8 | 14.3 | 11.5 | 1.02 | 0.06 | <0.58 | 2.0[illegible] |

106. Cation exchange capacity for the three upland locations was low and ranged from 0.08 to 3.40 meq/100 g soil. There was no trend in cation exchange capacity down the length of the core.

107. Sulfide content of the core sections was low and appeared to decrease slightly with depth in the profile. Sulfide values range from less than 0.58 to 1.26 μg/g.

108. Fertility analysis on the top section of each core is given in Table 25. Exchangeable calcium was very high and exceeded levels of 6000 #Ca/A. Exchangeable magnesium ranged from medium to high with values averaging around 220 #Mg/A. Extractable phosphorus (approximately 40 #$P_2O_5$/A) and exchangeable potassium (approximately 120 #$K_2O$/A) are in the low to medium range. No salinity hazard appeared to exist in the upper profile of the upland area when these samples were collected. Concentrations of available zinc, iron, and manganese ranged from medium to high.

109. Total analysis for eleven different metals on each core section showed no relative trends (Tables 20, 21 and 22). Calcium values fluctuated somewhat but these were probably due to the amount of shell material found in the soil samples. Higher calcium values were usually accompanied by increases in potassium, iron, magnesium, and manganese. Lead values ranged from 3.9 to 19.2 μg/g. Cadmium values usually averaged less than 1 μg/g down the cores. Mercury values ranged from 0.02 to 0.08 μg/g throughout the cores.

Intermediate sites

110. Sediment core and interstitial water analyses are given for sample cores taken from intermediate positions in the study site in Tables 26-31. Color, moisture content, texture, and pH at these three sites were similar to those for the upland sites.

111. Eh potentials for these locations were different from those of the upland locations. Generally the potentials were positive in the upper portion of the horizon and decreased with depth as the result of saturated conditions at the lower depths. In fact, moisture content was high enough that interstitial water samples could be collected from the upper horizons of cores 5 and 8 and from depths below 35 cm for core 2.

112. With the exception of core 5, organic matter percentage was low (< 0.09 percent). These low values were also apparent in the cor-

Table 25

Fertility Analysis of Surface Samples from Bolivar Peninsula as Determined by Standard Methods

Used by the Texas Agricultural Extension Service Soil Testing Laboratory

| Sample Location | Soil pH | Calcium (lbs/A* | level+) | Magnesium (lbs/A | level) | Phosphorus (lbs/A | level) | Potassium (lbs/A | level) | Sodium (lbs/A) | Salinity hazard | Zinc ppm | level | Iron ppm | level | Manganese ppm | level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Upland Sites | | | | | | | | | | |
| 1 | 8.4 | >6000 | VH | 210 | M | 44 | M | 140 | L | -- | none | 0.56 | M | 4.4 | M | 3.7 | H |
| 4 | 8.4 | >6000 | VH | 250 | M | 33 | L | 140 | L | -- | none | 0.54 | H | 8.8 | H | 3.7 | H |
| 7 | 7.9 | >6000 | VH | 210 | M | 44 | M | 90 | VL | -- | none | 0.90 | H | 4.8 | MH | 3.4 | H |
| | | | | | | | Intermediate Sites | | | | | | | | | | |
| 2 | 8.0 | >6000 | VH | 465 | H | 37 | L | 100 | VL | 250 | slight | 0.52 | M | 5.6 | H | 3.0 | H |
| 5 | 8.4 | >6000 | VH | 395 | H | 33 | L | 150 | L | -- | none | 0.56 | H | 8.0 | H | 3.0 | H |
| 8 | 8.6 | >6000 | VH | 330 | H | 20 | VL | 100 | VL | -- | none | 0.46 | H | 5.0 | MH | 4.7 | H |
| | | | | | | | Lowland Sites | | | | | | | | | | |
| 3 | 8.2 | >6000 | VH | >500 | H | 37 | L | 320 | H | 3180 | medium | 0.52 | H | 9.8 | H | 4.7 | H |
| 6 | 7.3 | >6000 | VH | >500 | H | 20 | VL | 350 | H | 2530 | medium | 0.67 | H | 16.0 | H | 5.2 | H |
| 9 | 8.1 | >6000 | VH | >500 | H | 33 | L | 410 | H | 2420 | medium | 0.74 | H | 12.4 | H | 3.9 | H |

*pounds per acre 6 inches

+VL = very low
L = low
M = medium
MH = medium high
H = high
VH = very high

Table 2B

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 2, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 5/2 | 7.00 | 99.10 | 0.00 | 1.25 | +451 | 7.10 | 0.07 | 16.0 | 0.71 | 0.191 |
| 10-35 | 10 YR 5/2 | 11.70 | 95.49 | 1.25 | 1.25 | +426 | 7.80 | 0.07 | 23.9 | <0.30 | 0.300 |
| 35-60 | 10 YR 4/1 | 16.90 | 97.02 | 1.25 | 1.25 | +456 | 8.10 | 0.09 | 19.6 | <0.30 | 0.525 |
| 60-85 | 10 YR 4/1 | 19.70 | 90.96 | 7.50 | 1.25 | - 44 | 7.70 | 0.08 | 52.4 | <0.30 | 0.750 |
| 85-107 | 10 YR 4/1 | 19.10 | 96.01 | 1.25 | 1.25 | - 84 | 8.50 | 0.05 | 16.0 | <0.30 | 0.333 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Nitrite-N (mg/ℓ) | Total Inorganic Nitrogen (mg/ℓ) | Total Phosphorus (mg/ℓ) | Ortho-phosphate (mg/ℓ) | Dissolved Organic Carbon (mg C/ℓ) |
|---|---|---|---|---|---|---|---|
| 35-60 | 0.00 | 2.95 | 0.018 | 2.96 | 0.396 | 0.225 | 3.50 |
| 60-80 | 0.12 | 1.16 | <0.005 | 1.28 | 0.422 | 0.320 | 2.30 |

Table [illegible]

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 2, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Calcium (μg/g) | Potassium (μg/g) | Sodium (μg/g) | Magnesium (μg/g) | Iron (μg/g) | Manganese (μg/g) | Zinc (μg/g) | Copper (μg/g) | Lead (μg/g) | Cadmium (μg/g) | Mercury (μg/g) | Sulfide (μg/g) | Cati[illegible] Excha[illegible] Capac[illegible] (meq/[illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 12,090 | 5,230 | 3,110 | 850 | 3,710 | 130 | 13.9 | 9.8 | 9.0 | 0.83 | —— | 1.78 | 0.[illegible] |
| 10-35 | 8,450 | 5,970 | 3,050 | 820 | 3,760 | 115 | 13.4 | 11.7 | 8.6 | 0.72 | 0.02 | 1.61 | 1.[illegible] |
| 35-60 | 25,910 | 11,710 | 6,730 | 1,800 | 8,350 | 153 | 13.7 | 16.2 | 9.0 | 1.00 | 0.06 | 2.60 | 1.[illegible] |
| 60-85 | 33,290 | [illegible],470 | 2,860 | 1,400 | 5,220 | 264 | 19.5 | 21.6 | 12.4 | 1.28 | 0.08 | 1.09 | 2.1 |
| 85-107 | 17,350 | 4,360 | 2,950 | 860 | 3,450 | 138 | 13.3 | 13.1 | 9.0 | 0.85 | 0.08 | <.50 | 0.6 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (μg/ml) | Potassium (μg/ml) | Sodium (μg/ml) | Magnesium (μg/ml) | Iron (μg/ml) | Manganese (μg/ml) | Zinc (μg/ml) | Copper (μg/l) | Lead (μg/l) | Cadmium (μg/l) | Mercury (μg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35-60 | 125 | 430 | 190 | 71 | 1.4 | 0.5 | 0.3 | <7.5 | <8 | <1 | <0.5 |
| 60-85 | 67 | 440 | 175 | 68 | 1.0 | 0.8 | 0.1 | <7.5 | <8 | <1 | <0.5 |

Table 28

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 5, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 4/2 | 23.5 | 97.08 | 2.50 | 0.00 | +456 | 7.30 | 0.40 | 238.2 | <0.30 | 0.383 |
| 10-35 | 10 YR 5/2 | 22.3 | 97.98 | 0.00 | 1.25 | +476 | 7.70 | 0.24 | 137.4 | 6.41 | 0.167 |
| 35-60 | 10 YR 4/2 | 18.1 | 98.08 | 0.00 | 1.25 | +346 | 7.70 | 0.93 | 21.0 | <0.30 | 0.125 |
| 60-85 | 10 YR 5/1 | 19.1 | 98.04 | 1.25 | 0.00 | +286 | 7.20 | 0.04 | 18.5 | <0.30 | 0.133 |
| 85-107 | 10 YR 5/1 | 18.9 | 98.50 | 1.25 | 0.00 | + 11 | 7.70 | 0.02 | 19.9 | <0.30 | 0.325 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Total Inorganic Nitrogen (mg/ℓ) | Total Phosphorus (mg/ℓ) | Ortho-phosphate (mg/ℓ) | Organic Carbon (mg C/ℓ) |
|---|---|---|---|---|---|---|---|
| 0-10 | 0.02 | 0.74 | 0.005 | 0.76 | ---- | <0.030 | 8.76 |
| 10-35 | ---- | 0.58 | 0.005 | 0.60 | 0.138 | <0.030 | 4.10 |
| 35-60 | 0.12 | 0.24 | 0.005 | 0.36 | 0.132 | <0.030 | 4.42 |

Table [illegible]

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 5,

an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Calcium (μg/g) | Potassium (μg/g) | Sodium (μg/g) | Magnesium (μg/g) | Iron (μg/g) | Manganese (μg/g) | Zinc (μg/g) | Copper (μg/g) | Lead (μg/g) | Cadmium (μg/g) | Mercury (μg/g) | Sulfide (μg/g) | Cation Exchange Capacity (meq/100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 6,890 | 3,830 | 3,150 | 1,110 | 3,950 | 108 | 17.4 | 16.4 | 12.0 | 0.64 | 0.04 | <.58 | 1.38 |
| 10-35 | 6,230 | 2,490 | 3,050 | 720 | 3,300 | 91 | 14.0 | 15.6 | 9.0 | 0.41 | 0.05 | <.58 | 1.74 |
| 35-60 | 7,070 | 2,990 | 2,990 | 650 | 3,[illegible]80 | 104 | 16.1 | 45.9 | 8.2 | 0.65 | 0.04 | <.58 | 0.22 |
| 60-85 | 7,870 | 4,730 | 3,670 | 1,160 | 4,400 | 106 | 16.2 | 13.2 | 10.[illegible] | 0.75 | 0.06 | <.58 | 0.19 |
| 85-107 | 7,840 | 4,990 | 3,080 | 690 | 3,100 | 85 | 11.6 | 9.9 | 8.6 | 0.65 | 0.04 | <.58 | 0.11 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (μg/mℓ) | Potassium (μg/mℓ) | Sodium (μg/mℓ) | Magnesium (μg/mℓ) | Iron (μg/mℓ) | Manganese (μg/mℓ) | Zinc (μg/mℓ) | Copper (μg/mℓ) | Lead (μg/ℓ) | Cadmium (μg/ℓ) | Mercury (μg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35-60 | 140 | 380 | 240 | 60 | 2.5 | 1.5 | 0.6 | <7.5 | <8 | <1 | <0.5 |
| 60-85 | 140 | 380 | 235 | 58 | 10.2 | 1.4 | 0.6 | <7.5 | <8 | <1 | <0.5 |

Table 30

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 8, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 5/2 | 19.1 | 99.72 | 1.25 | 0.00 | +276 | 7.00 | 0.09 | 65.8 | 0.36 | 0.167 |
| 10-35 | 10 YR 5/2 | 18.1 | 98.29 | 1.25 | 1.25 | +216 | 7.45 | 0.08 | 57.7 | 0.36 | 0.067 |
| 35-60 | 10 YR 5/ | 18.1 | 97.96 | 1.25 | 0.00 | +196 | 7.40 | 0.03 | 24.6 | <0.30 | 1.250 |
| 60-85 | 10 YR 5/2 | 18.4 | 98.44 | 0.00 | 1.25 | +206 | 7.50 | 0.04 | 19.6 | <0.30 | 0.167 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Nitrite-N (mg/ℓ) | Total Inorganic Nitrogen (mg/ℓ) | Total Phosphorus (mg/ℓ) | Ortho-phosphate (mg/ℓ) | Dissolved Organic Carbon (mg C/ℓ) |
|---|---|---|---|---|---|---|---|
| 0-10 | 0.02 | 0.42 | 0.010 | 0.45 | -- | 0.155 | 9.55 |
| 10-35 | 0.12 | 0.23 | <0.005 | 0.35 | -- | 0.155 | 6.69 |
| 35-60 | 0.20 | 0.36 | <0.005 | 0.56 | 2.090 | 0.075 | 5.30 |
| 60-85 | 0.12 | 1.00 | <0.005 | 1.12 | 0.598 | 0.075 | 4.80 |

Table 31

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 8, an Intermediate Location from the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Calcium (μg/g) | Potassium (μg/g) | Sodium (μg/g) | Magnesium (μg/g) | Iron (μg/g) | Manganese (μg/g) | Zinc (μg/g) | Copper (μg/g) | Lead (μg/g) | Cadmium (μg/g) | Mercury (μg/g) | Sulfide (μg/g) | Cati Exch Capac (meq/1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 6,440 | 4,730 | 2,930 | 690 | 3,100 | 83 | 13.0 | 13.7 | 10.2 | 0.76 | 0.05 | 0.66 | 0.8 |
| 10-35 | 11,000 | 8,920 | 7,560 | 1,830 | 7,990 | 80 | 16.0 | 21.8 | 8.6 | 0.74 | 0.02 | 0.62 | 1.3 |
| 35-60 | 7,470 | 6,470 | 2,920 | 660 | 3,300 | 81 | 12.8 | 12.4 | 8.6 | 0.72 | 0.05 | <0.58 | 0.8 |
| 60-85 | 7,410 | 6,460 | 2,920 | 610 | 3,090 | 91 | 12.7 | 13.7 | 8.2 | 0.70 | 0.03 | <0.58 | 0.8 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (μg/mℓ) | Potassium (μg/mℓ) | Sodium (μg/mℓ) | Magnesium (μg/mℓ) | Iron (μg/mℓ) | Manganese (μg/mℓ) | Zinc (μg/mℓ) | Copper (μg/ℓ) | Lead (μg/ℓ) | Cadmium (μg/ℓ) | Mercury (μg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35-60 | 105 | 430 | 345 | 105 | 6.8 | 0.7 | 0.9 | <7.5 | <8 | <1 | <0.5 |
| 60-85 | 88 | 460 | 1,375 | 115 | 8.3 | 2.8 | 5.0 | <7.5 | <8 | <1 | <0.5 |

responding low values for organic nitrogen. The two upper sections of core 5 were higher in organic matter with 0.40 and 0.24 percent for the 0-10 and 10-35 cm depths, respectively. Corresponding organic nitrogen concentrations were also high in these two sections with values of 238.2 and 137.4 mg N/kg.

113. Extractable ammonium-N was relatively low at all depths in the profiles except for the 10-35 cm section of core 5. The high value of 6.41 mg N/kg is unexplained.

114. Water-soluble phosphorus values were variable and not particularly related to depth. Concentrations ranged from 0.067 to 1.25 mg P/kg.

115. Cation exchange capacity of these sediment samples were very low and ranged from 0.1? to 2.10 meq/100 g soil.

116. Sulfide content was low in all profiles. The profile at location 2 had higher values than profiles at either location 5 or 8.

117. Fertility analysis on the top section of each of the three intermediate cores showed the same trends as the cores from the upland sites. Calcium and magnesium values were high whereas phosphorus and potassium values were low to very low. Zinc, iron, and manganese values were also high.

118. Total metal analysis on the core sections was similar to the cores from the upland sites of the study area. Calcium values at location 2 were very high opposed to locations 5 and 8. This is again due to the amount of shell material found in the core. The ranges of the other metals were similar to the upland cores and are documented in Tables 27, 29, and 31.

119. Interstitial water analyses were performed for those core sections where water could be extracted in the field. With the exception of the 0-10 and 10-35 cm section of core 2, some interstitial water was extracted at all depths which could be hand-sampled in the PVC pipes.

120. Concentrations of ammonium-, nitrate-, and nitrite-N in the interstitial water were generally low. Modest amounts of nitrate-N were present at all depths, but in general, concentrations of ammonium- and nitrite-N were barely detectable.

121. Total phosphate and orthophosphate concentrations in the interstitial water were generally low. When higher concentrations of

total phosphorus were present, they were associated with higher ortho-phosphate concentrations in solution. Interstitial water from core 5 was low in total phosphate as well as inorganic orthophosphate.

122. Dissolved organic carbon values were in the normal range for sediments. They ranged from 2.30 to 9.55 mg C/ℓ. Concentration of dissolved organic carbon tended to decrease with increasing depth.

123. Metal analysis on the interstitial water samples taken from locations 2, 5, and 8 were low compared to the metal content of the surrounding sediments. Cadmium values were less than one μg/ℓ, lead values less than 8 μg/ℓ and copper values were also low. Mercury values were all less than 0.5 μg/ℓ. The sodium content of the interstitial water taken from location 8 at a depth of 60-85 cm is high compared to the rest of the interstitial water samples. This is most likely due to the influence of sea water mixing in at these lower depths.

Lowland sites

124. Sediment cores were taken in the intertidal area during periods of low tide; analyses are in Tables 32-37. These sediments were essentially saturated with water at all times. The reduced conditions in the soil were generally apparent from the darker color of the sediments. This series of cores was grey and dark grey in color due to dissolved organic matter and sulfides (Tables 32, 34, and 36).

125. Moisture content of the sediments was generally greater than 18 percent throughout the profile. The lone exception was the 60 to 85-cm section of core 3, which had a moisture content of 15.8 percent.

126. Particle-size distribution was similar to that of cores taken from higher elevations except that there was considerably more silt present in the profiles. Percentage silt ranged from a low of 1.25 to a high of 7.5 percent. The percentage of clay also tended to be higher on the lowland sites compared to the other two sampling elevations.

127. Eh values were all negative, indicating the lack of oxygen throughout these profiles. There was a tendency for lower Eh readings at increasing depths for all profiles. This was expected since there would be some dissolved oxygen movement into the upper portions of the profile with the surface water.

128. pH values were generally higher than those recorded for the

Table 32

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 3, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 5/1 | 18.4 | 97.81 | 1.25 | 0.00 | + 96 | 7.60 | 0.06 | 23.1 | <0.30 | 0.167 |
| 10-35 | 10 YR 5/1 | 18.6 | 97.76 | 2.50 | 0.00 | + 46 | 7.70 | 0.05 | 27.4 | <0.30 | 0.158 |
| 35-60 | 7.5 YR 4/0 | 19.2 | 93.77 | 5.00 | 1.25 | -209 | 8.30 | 0.15 | 153.8 | <0.30 | 1.291 |
| 60-85 | 7.5 YR 4/0 | 15.8 | 93.93 | 3.75 | 2.50 | - 74 | 8.30 | 0.08 | 62.4 | <0.30 | 0.167 |
| 85-107 | 2.5 YR 4/0 | 18.9 | 94.04 | 5.00 | 0.00 | -104 | 8.40 | 0.12 | 63.4 | <0.30 | 0.208 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/L) | Nitrate-N (mg/L) | Nitrite-N (mg-L) | Total Inorganic Nitrogen (mg/L) | Total Phosphorus (mg/L) | Ortho-phosphate (mg/L) | Dissolved Organic Carbon (mg C/L) |
|---|---|---|---|---|---|---|---|
| 0-10 | 0.59 | 0.83 | <0.005 | 1.42 | 0.442 | 0.445 | 7.30 |
| 10-35 | 4.03 | 1.12 | 0.025 | 5.15 | 2.100 | 0.645 | 6.25 |
| 35-60 | 3.68 | 2.45 | 0.023 | 6.13 | 3.250 | 0.525 | 4.15 |

Table 21

**Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 3,**

**a Location Below Mean High Tide at the Bolivar Peninsula Study Site**

Sediment Analysis

| Core Section (cm) | Calcium (µg/g) | Potassium (µg/g) | Sodium (µg/g) | Magnesium (µg/g) | Iron (µg/g) | Manganese (µg/g) | Zinc (µg/g) | Copper (µg/g) | Lead (µg/g) | Cadmium (µg/g) | Mercury (µg/g) | Sulfide (µg/g) | Cation Exchange Capacity (meq/100g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 5,150 | 1,990 | 4,180 | 970 | 3,270 | 99 | 13.6 | 14.0 | 8.2 | 0.70 | 0.08 | 1.26 | 0.85 |
| 10-35 | 6,310 | 1,960 | 4,600 | 1,080 | 3,370 | 105 | 14.0 | 13.4 | 9.8 | 0.70 | 0.04 | 1.88 | 0.71 |
| 35-60 | 5,680 | 4,340 | 4,030 | 1,180 | 3,900 | 96 | 16.0 | 24.2 | 10.9 | 0.69 | 0.08 | 2.69 | 1.48 |
| 60-85 | 7,040 | 6,960 | 4,160 | 1,180 | 4,200 | 117 | 14.9 | 14.0 | 9.8 | 0.79 | 0.06 | 2.40 | 0.36 |
| 85-107 | 5,820 | 5,440 | 4,020 | 1,250 | 4,180 | 94 | 17.1 | 19.5 | 11.6 | 0.74 | 0.02 | 4.65 | 1.21 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (µg/mℓ) | Potassium (µg/mℓ) | Sodium (µg/mℓ) | Magnesium (µg/mℓ) | Iron (µg/mℓ) | Manganese (µg/mℓ) | Zinc (µg/mℓ) | Copper (µg/ℓ) | Lead (µg/ℓ) | Cadmium (µg/ℓ) | Mercury (µg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 350 | 710 | 6,300 | 580 | 1.2 | 0.8 | 2.4 | <7.5 | <8 | <1 | <0.5 |
| 10-35 | 295 | 600 | 4,980 | 470 | 5.0 | 4.5 | 0.2 | <7.5 | <8 | <1 | <0.5 |
| 35-60 | 270 | 590 | 4,550 | 430 | 5.6 | 12.7 | 0.3 | <7.5 | <8 | <1 | <0.5 |

Table [illegible]

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 6, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

| Core Sections (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 10 YR 3/1 | 19.8 | 95.90 | 2.50 | 1.25 | -174 | 7.40 | 0.80 | 105.4 | <0.30 | 0.575 |
| 10-35 | 10 YR 4/1 | 20.6 | 96.16 | 2.50 | 1.25 | -164 | 7.75 | 0.14 | 84.0 | <0.30 | 0.408 |
| 35-60 | 10 YR 4/1 | 18.8 | 94.52 | 3.75 | 1.25 | -234 | 7.70 | 0.09 | 52.0 | <0.30 | 0.125 |
| 60-85 | 10 YR 4/1 | 19.0 | 94.64 | 3.75 | 1.25 | -169 | 8.00 | 0.10 | 59.5 | <0.30 | 0.415 |
| 85-107 | 7.5 YR 4/0 | 18.6 | 94.00 | 3.75 | 2.50 | -224 | 7.90 | 0.13 | 82.6 | 0.71 | 0.575 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Total Inorganic Nitrogen (mg/ℓ) | Total Phosphorus (mg/ℓ) | Ortho-phosphate (mg/ℓ) | Dissolved Organic Carbon (mg C/ℓ) |
|---|---|---|---|---|---|---|---|
| 0-10 | 1.38 | 1.61 | <0.005 | 3.00 | 1.380 | 0.566 | 6.75 |
| 10-35 | 2.73 | 0.28 | <0.005 | 3.00 | 0.569 | 0.315 | 6.50 |
| 35-60 | 0.36 | 2.02 | 0.085 | 2.40 | 0.694 | 0.216 | 5.25 |

Table [illegible]

Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 6, a Location Below Mean High Tide at the Bolivan Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Calcium (µg/g) | Potassium (µg/g) | Sodium (µg/g) | Magnesium (µg/g) | Iron (µg/g) | Manganese (µg/g) | Zinc (µg/g) | Copper (µg/g) | Lead (µg/g) | Cadmium (µg/g) | Mercury (µg/g) | Sulfide (µg/g) | Cation Exchange Capacity (meq/100 g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 8,610 | 4,600 | 3,420 | 1,000 | 5,910 | 129 | 14.9 | 11.5 | 9.3 | 0.76 | 0.02 | 1.26 | 1.01 |
| 10-35 | 5,280 | 5,960 | 4,910 | 1,320 | 4,010 | 109 | 16.3 | 16.5 | 11.3 | 0.75 | 0.05 | 2.45 | 1.10 |
| 35-60 | 6,940 | 6,970 | 4,290 | 1,490 | 5,330 | 130 | 18.0 | 14.4 | 11.0 | 0.85 | 0.08 | 2.31 | 3.84 |
| 60-85 | 6,270 | 7,220 | 4,360 | 1,270 | 4,560 | 104 | 17.3 | 15.1 | 8.9 | 0.65 | 0.07 | 0.83 | 0.74 |
| 85-107 | 7,060 | 7,720 | 4,600 | 1,540 | 5,560 | 110 | 20.2 | 19.7 | 10.6 | 0.92 | 0.04 | 2.26 | 1.43 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (µg/mℓ) | Potassium (µg/mℓ) | Sodium (µg/mℓ) | Magnesium (µg/mℓ) | Iron (µg/mℓ) | Manganese (µg/mℓ) | Zinc (µg/mℓ) | Copper (µg/ℓ) | Lead (µg/ℓ) | Cadmium (µg/ℓ) | Mercury (µg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 340 | 690 | 5,700 | 860 | 1.8 | 7.2 | 0.6 | <7.5 | <8 | <1 | <0.5 |
| 10-35 | 270 | 640 | 4,800 | 460 | 1.5 | 1.4 | 0.1 | <7.5 | <8 | <1 | <0.5 |
| 35-60 | 270 | 820 | 4,850 | 430 | 1.9 | 2.2 | 0.2 | <7.5 | <8 | <1 | <0.5 |

Table [illegible]

Chemical and Physical Analyses of Sediments and Chemical Analysis of Interstitial Water Taken at Various Depths at Location 9, a Location Below Mean High Tide at the Bolivar Peninsula Study Site

Sediment Analysis

| Core Section (cm) | Color | Moisture Content (%) | Particle-Size Distribution (%) Sand | Silt | Clay | Eh (mv) | pH | Total Organic Matter (%) | Total Organic Nitrogen (mg/kg) | Ammonium (mg/kg) | Extractable Ortho-Phosphate (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 5 YR 5/1 | 23.[illegible] | 90.14 | 7.36 | 2.50 | + 36 | 7.50 | 0.22 | 115.4 | 1.78 | 0.292 |
| 10-35 | 5 YR 4/1 | 20.2 | 88.47 | 7.50 | 3.75 | + 86 | 8.40 | 0.12 | 49.5 | <0.30 | 0.292 |
| 35-60 | 5 YR 5/1 | 19.5 | 95.90 | 2.50 | 1.25 | -114 | 8.20 | 0.09 | 40.6 | <0.30 | 0.158 |
| 60-85 | 5 YR 5/1 | 18.7 | 93.44 | 3.75 | 2.50 | -144 | 8.30 | 0.12 | 61.9 | 1.42 | 0.208 |
| 85-107 | 5 YR 4/1 | 18.3 | 91.24 | 7.50 | 1.25 | -199 | 7.90 | 0.15 | 67.9 | <0.30 | 0.083 |

Interstitial Water Analysis

| Core Section (cm) | Ammonium-N (mg/ℓ) | Nitrate-N (mg/ℓ) | Nitrite-N (mg/ℓ) | Total Inorganic Nitrogen (mg/ℓ) | Total Phosphorus (mg/ℓ) | Ortho-phosphate (mg/ℓ) | Dissolved Organic Carbon (mg C/ℓ) |
|---|---|---|---|---|---|---|---|
| 0-10 | 1.31 | 0.58 | <0.005 | 1.90 | 0.622 | 0.625 | 4.64 |
| 10-35 | 3.18 | 2.96 | <0.005 | 6.14 | 0.070 | 0.025 | 4.74 |
| 35-60 | 0.14 | 2.24 | <0.005 | 2.40 | 1.512 | 0.488 | 5.10 |

Table 37

**Chemical Analyses of Sediments and Interstitial Water Taken at Various Depths at Location 9, a Location Below Mean High Tide at the Bolivar Peninsula Study Site**

Sediment Analysis

| Core Section (cm) | Calcium (µg/g) | Potassium (µg/g) | Sodium (µg/g) | Magnesium (µg/g) | Iron (µg/g) | Manganese (µg/g) | Zinc (µg/g) | Copper (µg/g) | Lead (µg/g) | Cadmium (µg/g) | Mercury (µg/g) | Sulfide (µg/g) | Cation Exchange Capacity (meq/100g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 6,070 | 5,340 | 4,600 | 1,430 | 4,900 | 118 | 20.3 | 24.2 | 11.7 | 0.76 | 0.03 | 3.15 | 2.78 |
| 10-35 | 7,500 | 4,100 | 6,200 | 1,810 | 5,620 | 146 | 19.4 | 18.4 | 9.3 | 0.76 | 0.05 | 2.66 | 1.92 |
| 35-60 | 5,300 | 3,490 | 5,360 | 1,330 | 4,140 | 103 | 16.9 | 18.8 | 9.3 | 0.70 | 0.06 | 2.63 | 1.54 |
| 60-85 | 6,580 | 6,590 | 4,910 | 1,280 | 4,330 | 102 | 17.3 | 19.0 | 9.8 | 0.76 | 0.02 | 2.29 | 1.55 |
| 85-107 | [illegible] | 7,840 | 5,170 | 1,640 | 5,580 | 130 | 21.2 | 27.8 | 14.8 | 0.82 | 0.04 | 2.20 | 2.43 |

Interstitial Water Analysis

| Core Section (cm) | Calcium (µg/mℓ) | Potassium (µg/mℓ) | Sodium (µg/mℓ) | Magnesium (µg/mℓ) | Iron (µg/mℓ) | Manganese (µg/mℓ) | Zinc (µg/mℓ) | Copper (µg/ℓ) | Lead (µg/ℓ) | Cadmium (µg/ℓ) | Mercury (µg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 340 | 650 | 5,750 | 570 | 1.8 | 6.2 | 3.0 | <7.5 | <8 | <1 | <0.5 |
| 10-35 | 300 | 580 | 4,600 | 440 | 2.0 | 8.8 | 0.1 | <7.5 | <8 | <1 | <0.5 |
| 35-60 | 280 | 620 | 4,630 | 450 | 2.1 | 6.7 | 0.1 | <7.5 | <8 | <1 | <0.5 |

129. Total organic carbon and total organic nitrogen followed trends similar to those reported for the previous sites. Exchangeable $NH_4^+$-N was low except for two horizons of core 9 where 1.78 and 1.42 mg/kg were recorded for the 0 to 10-and 60 to 85-cm sections, respectively.

130. Extractable orthophosphate was generally between 0.1 and 0.6 mg/kg. A value of 1.29 mg/kg was recorded for the 35 to 60 cm section of core 3.

131. Sulfide content was again low at each location but was higher than either the upland or intermediate sites. Values ranged from 0.83 μg/g to 4.65 μg/g. These higher values reflect the reducing conditions found at these lowland sites.

132. Cation exchange capacity was low as were the values from the upland and intermediate sites. Cation exchange values for the lowland sites ranged from 0.20 to 3.84 meq/100 g soil.

133. Fertility data on the lowland sites was somewhat different from that reported for the intermediate and upland sites. Calcium values were very high (>6000 #Ca/A). Magnesium values at locations 3, 6, and 9 were higher than those values from the other areas of the study site. Magnesium values at the lowland sites were greater than 500 pounds per acre. Phosphorus values were low and about the same as phosphorus values from the upland and intermediate sites. Potassium values from locations 3, 6, and 9 were high compared to potassium values from the rest of the study site. The lowland sites also had high sodium values and a medium salinity hazard as opposed to the upland and intermediate sites.

134. Metal concentrations at all three lowland locations were similar to values from those cores taken from the remaining study area. Calcium values on the lowland sites are not as variable as those from previous locations. This is probably an indication of more homogeneous core structures at the lowland sites. The magnesium and sodium values for the lowland sites appeared to be higher than the values from the upland and intermediate sites. This was probably due to the direct influence sea water has on the lowland cores in increasing the magnesium and sodium concentrations. Cadmium values were usually less than 0.8 μg/g and lead values averaged around 10 or 11 μg/g. Mercury values ranged from 0.02 to 0.08 μg/g.

135. Interstitial water samples from the lowland sites below mean high tide were collected from the top three sections. Both ammonium-N and nitrate-N concentrations were higher in these samples than for samples from similar depths at the intermediate elevations. For all three profiles, the concentration of ammonium-N was highest in the 10-35-cm section. Nitrite-N was low in these profiles with the highest concentration being 0.085 mg/ℓ.

136. Total phosphate and orthophosphate concentrations were also higher at these locations than for those at intermediate elevations. Concentrations as high as 3.25 mg/ℓ were measured at the 35- to 60-cm depth for core 3, and generally the values were above 0.4 mg/ℓ with corresponding orthophosphate concentrations of 0.2 mg/ℓ and greater. Core 9 had only 0.09 mg/ℓ total phosphate and 0.025 mg/ℓ orthophosphate in the 10-to 35-cm depth.

137. Dissolved organic carbon was between 4.64 and 7.30 mg/ℓ in all interstitial water samples for the lowland sites. These values could be classified as normal for these sediments.

138. Metal analysis on the interstitial water samples taken from the lowland sites are shown in Tables 33, 35, and 37. Calcium, potassium, sodium and magnesium values were all higher than interstitial water values taken at the intermediate sites. This is expected since the lowland sites are in contact with sea water which causes the increases found in the major cations (Ca, K, Na, Mg). Upland areas are partially leached of those cations due to movement of rain water through the profile. Manganese concentrations in interstitial water from the lowland sites are also somewhat higher than at the intermediate sites. Copper, zinc, lead, cadmium, and mercury values at the lowland locations are similar to those found at the intermediate sites.

## PART VII: CONCLUSIONS

139. A total of 74 plant species representing 61 genera and 20 families were collected and identified from the study site during a 5-month summer and early fall period. Gramineae, Compositae, and Cyperaceae were the most important families. The average basal cover was over 13 percent with litter cover exceeding 15 percent. The dominant grasses were marshay and bluestem. Forb density was over 10 plants/square foot; camphorweed was the most commonly occurring species. Woody plant density exceeded 3,200 plants/acre with drummond sesbania the most common species. The only other woody species to occur was gulf croton.

140. Six plant communities were identified and mapped. These were, in order of area occuppied: (a) *Andropogon perangustatus*, (b) *Spartina patens*, (c) *Sesbania*-mixed grass, (d) *Sporobolus virginicus*-*Distichlis spicata*, (e) *Monarda citriodora*, and (f) *Spartina alterniflora*. Biomass production exceeded 4,100 pounds/acre in both the *Andropogon perangustatus* and *Spartina patens* communities.

141. Bird species recorded increased from 41 in July to 50 in September, totalling 98. Red-winged blackbirds were the most numerous species. Thirteen mammal species were recorded, three of them domestic. The most common were hispid cotton rats, raccoon, and domestic goat. The cotton rat population was estimated at an average of 30/acre. A total of 31 reptiles and amphibians representing 11 species were observed on the study site. Eighteen orders of macroinvertebrates were collected and identified. The most common forms were grasshoppers, land snails, mud fiddler crabs, and tiger beetles.

142. All soil and sediment samples in the study site were sandy to a depth of 107 cm, ranging from 88 to 99 percent sand. Total organic carbon was less than 0.2 percent except where evidence of some plant residue occurred. Values of Eh varied from +500 mv for oxidized horizons to near -240 mv in the intertidal zone. The Eh was related to soil moisture content.

143. Interstitial water samples did not contain excessive concentrations of ammonium, nitrite-, or nitrate-N. Total inorganic nitrogen did not exceed 6.14 mg/ℓ. Total phosphorous and orthophosphate concentrations in interstitial water were less than 3.25 and 9.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ.

144. Flora and fauna of the study site were low, both in terms of diversity and density. Chemical composition of the sediments corresponded to the sandy nature of the material. Excessive nutrient concentrations were not evident. Thus, the study site is below potential productivity and use for coastal marshes.

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APPENDIX A

SPECIES LIST FOR THE BOLIVAR PENNINSULA HABITAT DEVELOPMENT SITE,

GALVESTON BAY, TEXAS

| Family-Scientific name | Common Name |
|---|---|
| Asclepiadaceae | |
| Cynanchum angustifolium Pers. | Swallowwort |
| Boraginaceae | |
| Heliotropium curassavicum L. | Salt heliotrope |
| Capparidaceae | |
| Polanisia trachysperma var. trachysperma (T.&G.) Iltis | Roughseed clammyweed |
| Chenopodiaceae | |
| Chenopodium ambrosioides L. | Wormseed goosefoot |
| Salicornia bigelovii Torr. | Bigelow glasswort |
| Commelinaceae | |
| Commelina angustifolia Michx. | Narrowleaf dayflower |
| Compositae | |
| Ambrosia psilostachya DC. | Western ragweed |
| Aphanostephus skirrhobasis var. thaliassius (DC.) Trel. Shinners | Coast dozedaisy |
| Conyza canadensis (L.) Cronquist | Horsetail conyza |
| Erechtites hieracifolia (L.) Raf. | American burnweed |
| Erigeron myrionactis Small | Corpus Christi fleabane |
| Eupatorium compositifolium Walt. | Yankeeweed |
| Euthamia leptocephala (T.&G.) Greene | (none) |
| Gaillardia pulchella Foug. | Rosering gaillardia |
| Helenium amarum (Raf.) H. Rock | Sneezeweed |
| Helianthus debilis Nutt. ssp. praecox (Engelm.&Gray) Heiser | Early cucumberleaf sunflower |
| Heterotheca subaxillaris (Lam.) Britt&Rusby | Camphorweed |
| Iva angustifolia var. angustifolia Nutt. | Narrowleaf sumpweed |
| Iva frutescens L. | Bigleaf sumpweed |
| Pluchea purpurascens (SW.) DC. | Purple pluchea |
| Solidago sempervirens L. var. mexicana (L.) Fern | Seaside goldenrod |
| Convolvulaceae | |
| Ipomoea sagittata Poir. | Saltmarsh morningglory |

| Family-Scientific Name | Common Name |
|---|---|
| Cyperaceae | |
| Cyperus articulatus L. | Jointed flatsedge |
| Cyperus ovularis (Michx.) Torr. var. ovularis | Globe flatsedge |
| Cyperus ovularis (Michx.) Torr. var. cylindricus (Will.) Torr. | Cylinder flatsedge |
| Cyperus polystachyos Rottb. | (none) |
| Eleocharis albida Torr. | White spikesedge |
| Eleocharis macrostachya Britton | Largespike Spikesedge |
| Fimbristylis carolinianum (Lam.) | Fimbry |
| Scirpus americanus Pers. | American bulrush |
| Euphorbiaceae | |
| Croton capitatus Michx. | Woolly croton |
| Croton punctatus Jacq. | Gulf croton |
| Euphorbia ammannioides T.&G. | Ingalls euphorbia |
| Gentianaceae | |
| Sabatia campestris Nutt. | Prairie rosegentian |
| Gramineae | |
| Andropogon glomeratus (Walt.) B.S.P. | Bushy bluestem |
| Andropogon perangustatus Nash. | Bluestem |
| Aristida longaespica Poir var. longaespica | Slimspike threeawn |
| Aristida oligantha Michx. | Old field threeawn |
| Cenchrus incertus M.A. Curtis | Common sandbur |
| Cynodon dactylon (L.) Pers. | Bermudagrass |
| Distichlis spicata (L.) Green var. spicata | Seashore saltgrass |
| Eragrostis oxylepis (Torr.) Torr. | Red lovegrass |
| Eragrostis silveana | (none) |
| Eustachys petraea (Swartz) Desv. | (none) |
| Muhlenbergia capillaris (Lam.) Trin. | Hairyawn muhly |
| Panicum repens L. | Torpedograss |
| Paspalum monostachyum Vassey | Gulfdune paspalum |
| Paspalum setaceum Michx. var. setaceum | Thin paspalum |
| Polypogon monspeliensis (L.) Desf. | Rabbitfoot polypogon |
| Setaria geniculata (Lam.) Beauv. | Knotroot bristlegrass |
| Spartina alterniflora Loisel. | Smooth cordgrass |
| Spartina patens (Ait.) Muhl. | Marshay |
| Spartina spartinae (Trin.) Merr. | Gulf cordgrass |
| Sporobolus indicus (L.) R. Br. | Smutgrass |
| Sporobolus pyramidatus (Lam.) Hitchc. | Whorled dropseed |
| Sporobolus virginicus (L.) Kunth | Seashore dropseed |
| Triplasis purpurea (Walt.) Chapm. | Purple sandgrass |

| Family-Scientific Name | Common Name |
|---|---|
| Labiatae | |
| Monarda citriodora Cerv. | Lemon beebalm |
| Leguminosae | |
| Astragalus nuttallianus DC. var. nuttallianus | Nuttail milkvetch |
| Cassia fasciculata Michx. var. fasciculata | Prairie senna |
| Medicago lupulina L. | Black medic |
| Neptunia lutea (Leavenw.) Benth | Yellow neptunia |
| Prosopis glandulosa Torr. var. glandulosa | Honey mesquite |
| Psoralea rhombifolia Torr. & Gray | Roundleaf scurfpea |
| Sesbania drummondii (Rydb.) Cory | Drummond sesbania |
| Trifolium sp. | |
| Malvaceae | |
| Kosteletzkya virginica (L.) Gray | Virginia saltmarshmallow |
| Primulaceae | |
| Samolus ebracteatus H.B.K. ssp. alyssoides * (Heller) R. Kunth | Coast brookweed |
| Rubiacea | |
| Galium tinctorium L. | Dye bedstraw |
| Scrophulariaceae | |
| Agalinis maritima (Raf.) Raf. | Saltmarsh gerardia |
| Solanaceae | |
| Physalis viscosa L. var. spathulaefolia (Torr.) Gray | Groundcherry |
| Solanum elaeagnifolium Cav. | Silverleaf nightshade |
| Umbelliferae | |
| Hydrocotyle bonariensis Lam. | Largeleaf pennywort |
| Verbenaceae | |
| Lantana horrida H.B.K. | Common lantana |
| Phyla incisa Small | Sawtooth frogfruit |
| Verbena xutha Lehm. | Coarse verbena |

## APPENDIX B'

## PHYSICAL DESCRIPTION OF SOIL CORES

| Core No. | Depth (cm) | Description |
|---|---|---|
| 1 | 0-25 | Sand, fine grain, massive, unconsolidated. |
| | 25-26 | Sand, fine grain, dark brown clay. |
| | 26-73 | Sand, fine grain, massive, unconsolidated, organic matter, trace shells. |
| | 73-80 | Clay and sand, very fine grain, grey to brown in color. |
| | 80-87 | Sand, fine grain, massive, unconsolidated, organic matter, trace shells. |
| | 87-107 | Sand, fine grain, unconsolidated, shell fragments (dredge). |
| 2 | 0-31 | Sand, fine grain, massive, unconsolidated, well sorted. |
| | 31-33 | Sand and silt, fine grain, horizontal bedding. |
| | 33-49 | Sand, fine to medium grain, massive, unconsolidated, shell fragments. |
| | 49-54 | Dredge fill, poorly sorted, sand, shell fragments. |
| | 54-59 | Sand, fine to medium grain, some shell fragments. |
| | 59-98 | Sand and silt, fine to medium grain, dredged material shell fragments, mud clasts, poorly sorted. |
| | 98-107 | Sand, fine to medium grain, massive. |
| 3 | 0-8 | Sand, fine grain, well sorted, horizontal bedding. |
| | 8-23 | Sand, fine to medium grain, well sorted, some horizontal bedding: sand, silt, sand. |
| | 23-60 | Sand, fine grain, some silt, well sorted, trace shell fragments, some horizontal bedding. |

| Core No. | Depth (cm) | Description |
|---|---|---|
| | 60-107 | Sand, fine grain, some silt, well sorted, trace shell fragments, some horizontal bedding. |
| 4 | 0-10 | Sand, fine grain, some organic matter, shell fragments, massive, unconsolidated. |
| | 10-107 | Sand, fine grain, massive, unconsolidated, well sorted. |
| 5 | 0-4 | Sand and clay, very fine grain, some organic matter. |
| | 4-19 | Sand, fine grain, massive unconsolidated. |
| | 19-20 | Sand and clay, very fine grain, some organic matter. |
| | 20-107 | Sand, fine grain, unconsolidated, some plant material. |
| 6 | 0-107 | Sand, fine to very fine grain, unconsolidated, well sorted, some shell fragments, some horizontal bedding down entire core, pockets of silt. |
| 7 | 0-57 | Sand, fine grain, massive, unconsolidated, well sorted, trace shell fragments, some organic matter. |
| | 57-92 | Sand, medium grain, massive, unconsolidated trace shell fragments, organic matter. |
| | 92-94 | Sand and silt, fine grain, some horizontal bedding, shell fragments, grey in color. |
| | 94-107 | Sand, fine grain, poorly sorted, some silt, some organic matter. |
| 8 | 0-32 | Sand, fine to medium grain, massive, unconsolidated, organic matter, shell fragments. |
| | 32-34 | Sand, fine grain, some horizontal bedding, some silt. |
| | 34-107 | Sand, fine to medium grain, massive unconsolidated, some organic matter, some shell fragments. |

| Core No. | Depth (cm) | Description |
|---|---|---|
| 9 | 0-20 | Sand, fine grain, massive, unconsolidated, well sorted, some shell fragments, some silt, some horizontal bedding. |
| | 20-33 | Sand, fine grain, some silt, well sorted, organic matter, shell fragments, some horizontal bedding. |
| | 33-107 | Sand, fine to medium grain, well sorted, some silt, organic matter, shell fragments, some horizontal bedding. |

... letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Dodd, J D

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix B: Baseline inventory of terrestrial flora, fauna, and sediment chemistry / by J. D. Dodd ... [et al.], College of Agriculture, Texas A&M University, College Station, Tex. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

92, 3, 3 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-15, Appendix B)

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References: p. 90-92.

1. Animals. 2. Birds. 3. Bolivar Peninsula. 4. Dredged material. 5. Field investigations. 6. Galveston Bay. 7. Habitats. 8. Mammals. 9. Marshes. 10. Plants (Botany).

(Continued on next card)

Dodd, J D

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11. Sediment. 12. Sediment sampling. 13. Soil chemistry. I. Texas. A & M University, College Station. College of Agriculture. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15, Appendix B.

TA7.W34 no.D-78-15 Appendix B